Iron and Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

JULY, 1950

TECHNOLOGY DEPT.
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The WEAN ENGINEERING COMPANY INC.
WARREN, OHIO

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DETROIT

To better serve the requirements of the trade and to operate at a profit in a highly competitive field, steel plant executives recognize they must have the most modern and efficient equipment available.

The Wean Engineering Company, Inc., Warren, Ohio, is the recognized leader in the design and installation of sheet, tin and strip mill equipment, whether it be one piece or a complete unit.

Many steel mill executives, both in this country and abroad, have recognized the advantages and efficiency of WEAN SHEET, STRIP AND TIN MILL EQUIPMENT. The same recognized advantages are available for overcoming your problems.

SPECIALISTS IN SHEET, TIN and STRIP MILL EQUIPMENT

JR v.27 2 July-Dec. 1950

why there can be

NO OTHER ANSWER IN SAFETY SWITCH SELECTION

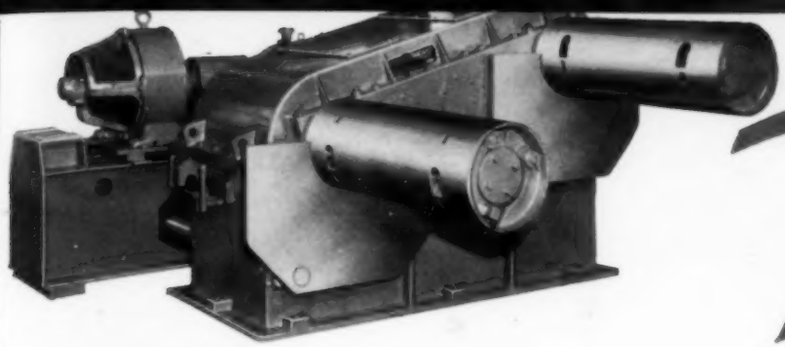
Engineering research authenticated by outstanding authorities has conclusively established "internal heating" to be the principal cause of safety switch failures. This "internal heating" literally bakes the life right out of safety switch parts, causing insulating materials to disintegrate and metal parts to distort and corrode. The safety switch then either becomes inoperative or it "burns up" through inability to carry the load.

In properly constructed safety switches, fuses are almost entirely responsible for this destructive "internal heating." This is not a criticism of fuses for *any* fuse operating up to its rated load *must* be near its melting point if it is to perform properly when an overload occurs. And any metal operating *near* its melting point *must* be hot . . . and fuse links are *hot* . . . with temperatures running as high as 700 degrees Fahrenheit.

Since you cannot vent trapped heated air through a safety switch enclosure and still keep a safety switch *safe*, the only escape from the ravages of "internal heating" *must* come through the selection of materials for the internal safety switch structure and the design of that structure to *withstand successfully the unavoidable heat conditions met in safety switch service.*

Cutler-Hammer Safety Switches were completely redesigned in this way *ten years ago* to beat "internal heating" when engineering research clearly indicated the need for *such* safety switches. Nine years of experience shows the Cutler-Hammer claim of better safety switch performance far more than a mere promise; it is a proven *fact* that demonstrates why there can be no other answer in safety switch selection. CUTLER-HAMMER, Inc., 1269 St. Paul Ave., Milwaukee 1, Wisconsin.

IRON AND STEEL ENGINEER; published monthly by Association of Iron and Steel Engineers, 1010 Empire Bldg., entered as second class matter January 25, 1924 at Pittsburgh, Pennsylvania, under Act of Congress, March 3, 1879. $7.50 per year in United States and Canada, $10.00 foreign countries. Volume 27, No. 7



Double drum type tight coiler.

Tension Reels...

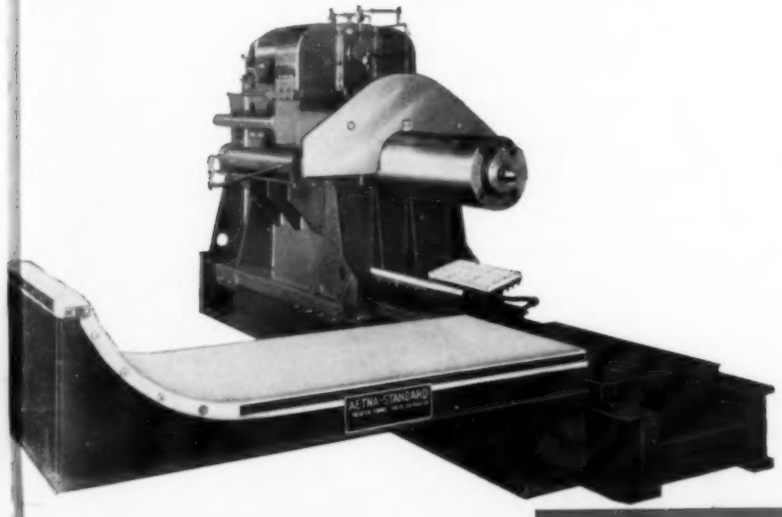
REELS FOR ANY SIZE COIL

Retractable drum type tight coiler.

• Coils in any commercial width or weight can be handled quickly and easily with Aetna Tension Reels. Rigid expansion is maintained without use of links.

With an Aetna-Standard reel you can have either hydraulic or mechanical lift and traverse; air or hydraulic operation for head expansion or stripper. Removable shoes permit handling of wide range of inside diameters. Reels furnished with or without unloading facilities.

Illustrated here are typical Aetna-Standard reels. Write Aetna-Standard for information for your specific requirements. Our flat-rolled specialists are available to you.



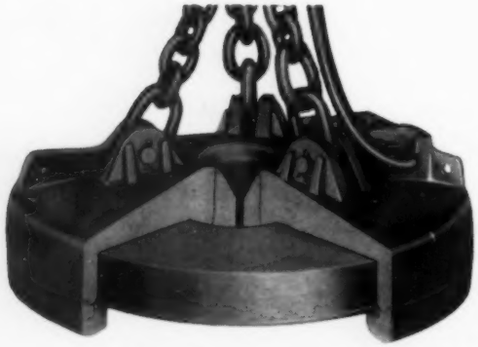
Tension Reel with coil carriage and unloading ramp.

THE AETNA-STANDARD ENGINEERING COMPANY
YOUNGSTOWN, OHIO
ASSOCIATED COMPANIES
AETNA-STANDARD ENGINEERING CO., LTD., TORONTO, ONTARIO, CANADA
HEAD, WRIGHTSON & COMPANY, LTD., THORNABY-ON-TEES, ENGLAND
SOCIETE DE CONSTRUCTIONS DE MONTBARD, 6 RUE DARU, PARIS (8e) FRANCE

SALVAGE OPERATIONS have begun on recovery of two barges of pig iron which sank in the river above Lovers' Leap, Monday evening. One barge is partially in view while the other one is completely underneath the water. A large magnet is being used to haul the pig iron from the river to railroad cars which are waiting on the tracks in the right of the photo. There are approximately 25 carloads of iron on the two barges.—Staff photo.

ALTON EVENING TELEGRAPH THURSDAY, APRIL 13, 1950

25 Carloads of Pig Iron Quickly Salvaged by EC&M *All Welded* Lifting Magnet



Double-sealed against moisture —a watertight coil within a ***watertight*** housing.

Taken from regular steel mill service, an EC&M 55-inch diameter Type SW *All-Welded* Lifting Magnet efficiently salvaged the pig iron from two barges which sank in the Mississippi River at Alton, Illinois.

The EC&M *All-Welded* Lifting Magnet was selected for this operation because the plant management had confidence that the all-welded construction of the EC&M Magnet would withstand the underwater service and they knew, from experience, that the pig iron would be recovered in a minimum number of lifts. There were no bolts to tighten, no special attention needed to put the magnet in shape for quick recovery of this sunken cargo.

The *All-Welded* design of EC&M Type SW Lifting Magnets keeps moisture out of the coil and maintains lifting ability.

WRITE FOR BULLETIN 900

which shows the details that give *high output at low upkeep.*

THE ELECTRIC CONTROLLER & MFG. CO.

2698 EAST 79TH STREET • CLEVELAND 4, OHIO

MESTA

FORGED HARDENED STEEL WORKING ROLLS *for Cold Mills*

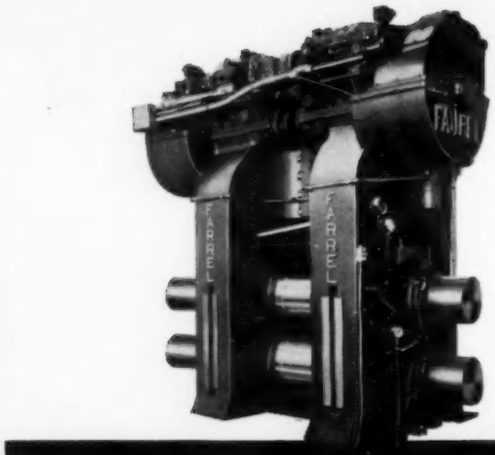
Finishing a 21" x 98" Mesta Forged Hardened Steel Working Roll, for use in modern high speed Cold Reduction Mills as shown above, in a Mesta 28" Traveling Table Type Roll Grinder.

Designers and Builders of Complete Steel Plants

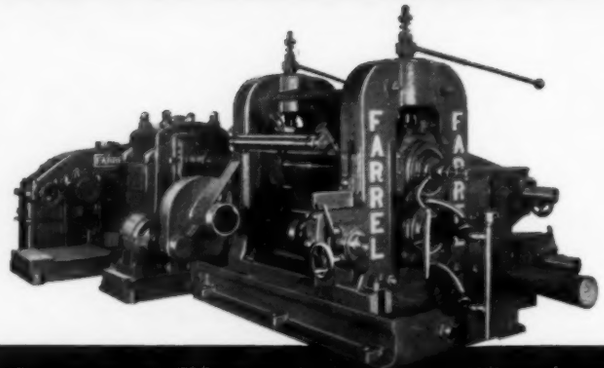
MESTA MACHINE COMPANY

PITTSBURGH, PENNSYLVANIA

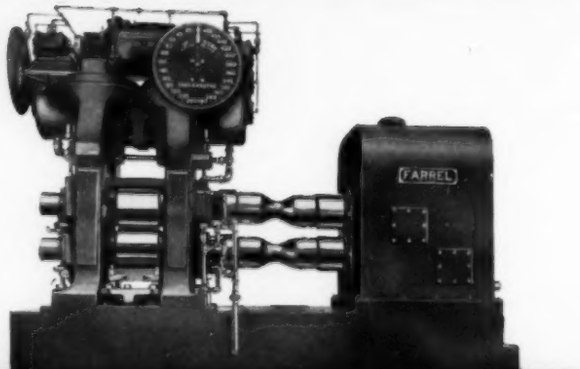
FARREL® MILLS FOR ROLLING



1. NONFERROUS METALS



2. METAL FOILS



3. COLD STRIP STEEL

For almost a century, Farrel mills have been helping to solve rolling mill production problems. Designed to meet specific requirements, they are built in a wide range of types and sizes for rolling nonferrous rods, strips or sheets, metal foils and cold strip steel.

The company also designs and manufactures the reduction gear drives and pinion stands, coilers and special handling equipment required to make each installation a complete unit.

Farrel engineers are prepared to design mills for the solution of your production problems. Write for quotations on mills for specific applications.

FARREL-BIRMINGHAM COMPANY, INC.

ANSONIA, CONNECTICUT

Plants: Ansonia and Derby, Conn., Buffalo, N. Y.
Sales Offices: Ansonia, Buffalo, New York, Akron, Pittsburgh, Chicago, Los Angeles, Houston

For preliminary information about rolling mills to suit your particular requirements, please furnish the following details:

Kind of metal . . . daily production . . . hot or cold rolling . . . starting thickness and final gauge . . . maximum and minimum width . . . method of handling during rolling . . . alternating or direct current.

1. 28" x 30" two-high cold brass running-down mill, with double motor screwdown.

2. 14" x 42" two-high double let-off foil mill, with wind-up, wiper attachments and ironing roll.

3. 10" x 10" two-high reversing cold strip mill, with single reduction drive and pinion stand mounted on common base with mill.

FB-582

Farrel-Birmingham®

Established 1836

LUBRICATION DAN SEZ:
IN 1869 THE GOLDEN SPIKE WAS DRIVEN
JOINING THE EAST WITH THE WEST
7 years later (1876) our Company began
working with "BLACK GOLD" and in 1950
it's LEADOLENE*
Klingfast

CHECK THESE 9 IMPORTANT FACTS

1. **EXTREME PRESSURE pH-ilm STRENGTH** of 50,000 lbs. per square inch minimum by "Timken" testing machine.
2. **ADHESIVENESS** in which affinity for steel and other metals develops maximum adhesion and prevents drippage or creeping. Retains a flexible coating in nature.
3. **WATER REPELLENCE** which retards washing off, creates a lubricating pH-ilm under moisture or water conditions.
4. **CORROSION PREVENTION** is an excellent protective coating in that it will not etch or corrode metals. Is never acidic.
5. **COMPOUNDED STABILITY**—Will not bleed or change physical condition within range of higher than usual temperatures for this type of lubricant.
6. **LOW TEMPERATURE FACTORS**—While having a solidifying action by decreased temperature as low as —40 F., it does not harden, crack or decrease in adhesion. The flexible coating withstands distortion of the application.
7. **ABRASIVE RESISTANCE**—Extremely high for a lubricant. Does not wipe off nor will be removed in handling by workmen's hands or gloves. Is extremely repellent to adhesion of scale, metallics and other forms of dusts or contamination.
8. Klingfast has remarkable corrosive resistance to salt or sea water, acidic vapors and solutions.
9. Klingfast can be removed by ordinary solvents such as kerosene, gasolene, naphtha, carbontetrachloride and similar substances but is highly impervious to lubricating oils and greases.

. . . Leadolene KLINGFAST does the important protective jobs, **economically**—for leading ferrous and non-ferrous producers, metal fabricators, automotive manufacturers, wire rope manufacturers and users, railroads, coal operations above ground and below, sugar industry both domestic and foreign. **And for every single application, Leadolene KLINGFAST had to prove conclusively under the most exhaustive tests that it provided greater protection, with more economy, and laboratory-proved indestructible pH-ilm,** to meet the job application.

Phone, wire or write for an adequate sample to test in your own plant without obligation.

***LEADOLENE . . . the "I. P. Lubricant" (Indestructible pH-ilm) . . . for Industrial Needs**

The Brooks Oil Co.

Since 1876

Pittsburgh 12, Pennsylvania
Cleveland, Ohio
Hamilton, Ontario
Warehouses in Principal Industrial Cities

YOU CAN BE **SURE**.. IF IT'S

Westinghouse

Something *NEW* has been added to SK DEPENDABILITY

You know the SK motor as the most dependable d-c motor in the business. Thirty-nine years of tough, rugged service have proved it. Now, retaining all the basic features of the old SK, we've added something new to bring new value to d-c motor users.

CAST BRASS BRUSHHOLDERS . . . are non-corroding. May be removed individually through spacious front openings. Stainless steel spring retains constant tension on brush.

MELAMINE ROCKER RING . . . is noncarbonizing when arcs occur across its surface. There's no tracking effect . . . no "burned in" paths to cause shorts that reduce motor efficiency.

PRE-LUBRICATED BALL BEARINGS . . . need no lubrication. Eliminate trouble and cost of greasing attention. Dirt stays out . . . grease stays in.

REINFORCED END BRACKETS . . . provide maximum rigidity, strength and correct bearing alignment . . . stand up to the shocking, jarring blows so often encountered in rugged d-c service.

SNAP-ON COVERS . . . eliminate screws and bolts. Stainless steel spring clips allow covers to be snapped on easily. To remove, just pry off with a screw driver.

TUFVAR WIRE . . . adds life to armature. Tougher, more flexible than conventional enamel, it stands up to long heat exposure . . . shows no tendency to crack or become brittle.

TAKE A MOTOR APART AND SEE. Ask your Westinghouse representative to show the Life-Line D-C Motor "Transvision". It takes a motor apart and puts it together again on your own desk top. You'll see the inside story of SK dependability . . . see why something new has been added. Call your local representative today. Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pa. J-21550

Westinghouse *Life-Line* D-C Motors

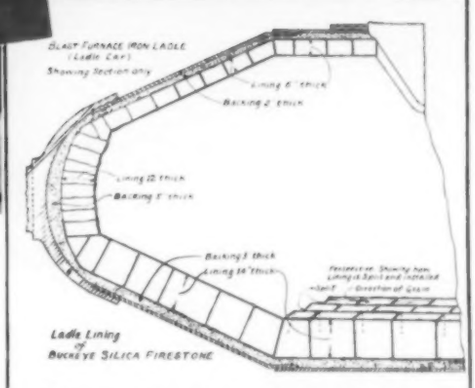
BUCKEYE SILICA FIRESTONE LADLE LININGS CARRY AS HIGH AS 100,000 TONS BEFORE REPLACEMENT!

Buckeye Silica Firestone linings average about 55,000 tons of iron in 80-ton ladles and about 75,000 tons . . in 125-ton ladles. In many instances, linings have carried over 100,000 tons of metal before being replaced!

This means less downtime . . unusual economies . . less labor for repairs. Ordinarily, the cost of skulling out the old lining and completely relining with Buckeye Silica Firestone is less than one cent per ton of metal carried!

For superior performance, specify Buckeye Silica Firestone — hundreds of steel mill executives recommend it as the finest refractory material on the market. Write for full information.

THE CLEVELAND QUARRIES CO.
REFRACTORY DEPT.
1740 E. Twelfth Street CLEVELAND 14, OHIO



Here is a typical installation of Buckeye Silica Firestone in a sectional view of a ladle. This provides some idea of the ease and quickness with which Buckeye may be installed.

Complete instructions for the installation of Buckeye Silica Firestone in blast furnace ladles are available upon request. Our service organization is prepared to assist you in the use and installation of Buckeye.

BUCKEYE
"FOR THAT EXTRA SERVICE"
SILICA FIRESTONE

Specify N-B-M BRONZE CASTINGS

for higher steel mill production...lower costs!

Custom-engineered alloys — plus close foundry control — insures longer, more economical service

Longer life means less down-time . . . actual dollar-savings in the operating costs of your mill. You specify longer life when you specify N-B-M Bronze Castings . . . because of this important 3-Way Service offered by National Bearing Division:

Research . . . that in case after case has developed new alloys that roll up new tonnage records.

Engineering . . . that results in new and better designs to help solve old maintenance and production problems.

Facilities . . . for close foundry control that insures sound, dense castings—as-cast or machined to any degree of finish you desire.

From huge screw-down nuts to a complete line of Cored and Solid Bars for small bearings and bushings, put this 3-Way Service to work in your mill!

All types of Manganese, Aluminum, Nickel and High Tensile Bronze Alloys ...produced to your specifications or from our own service-proved formulas

AMERICAN Brake Shoe COMPANY

NATIONAL BEARING DIVISION

4936 Manchester Avenue • St. Louis 10, Mo.

PLANTS IN: ST LOUIS, MO • MEADVILLE, PA. • NILES, OHIO • PORTSMOUTH, VA. • ST. PAUL, MINN. • CHICAGO, ILL.

Loading up...FOR A 40% SAVING

CUT UP TO $200,000 A YEAR FROM REFUSE DISPOSAL COSTS

From Open Hearth to Dump and back again. That can be a costly operation or just a normal operating expense.

It all depends on the equipment used.

Gondola, hopper or obsolete air dump cars run the cost of refuse disposal way up out of sight. They're not built for the job. The heat of lading and banging of buckets makes maintenance and repair quite a sizeable item on your annual budget. On top of that, there's added labor costs, loss of operating time and haulage waste due to inefficient equipment.

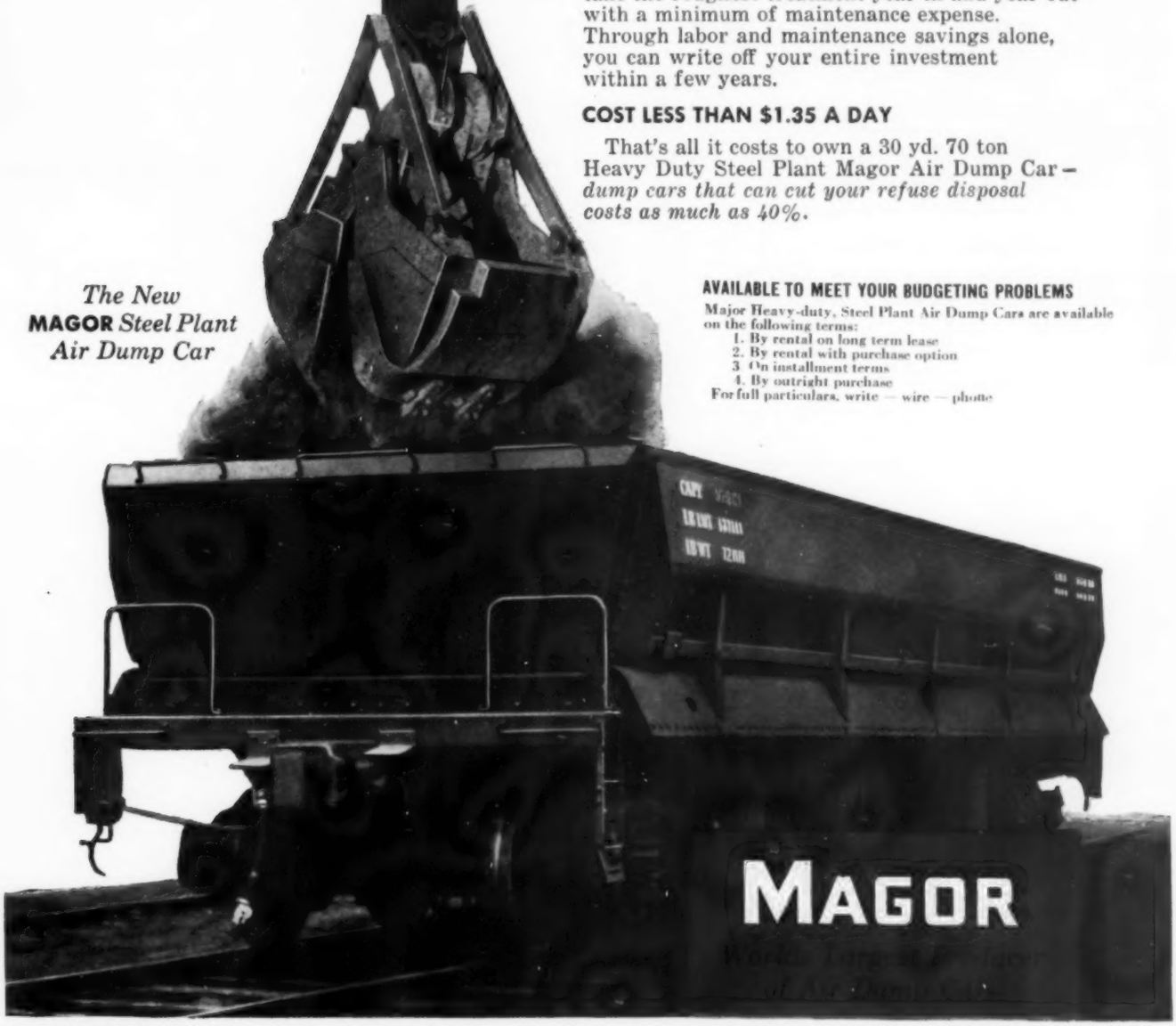
Here's how you can bring those costs down within reach and maintain an even higher degree of operating efficiency – New Magor Air Dump Cars – built specifically for steel plant service.

New Magor Air Dump Cars are a modern low-cost approach to refuse disposal. They can take the roughest treatment year in and year out with a minimum of maintenance expense. Through labor and maintenance savings alone, you can write off your entire investment within a few years.

COST LESS THAN $1.35 A DAY

That's all it costs to own a 30 yd. 70 ton Heavy Duty Steel Plant Magor Air Dump Car – *dump cars that can cut your refuse disposal costs as much as 40%.*

The New **MAGOR** *Steel Plant Air Dump Car*



AVAILABLE TO MEET YOUR BUDGETING PROBLEMS

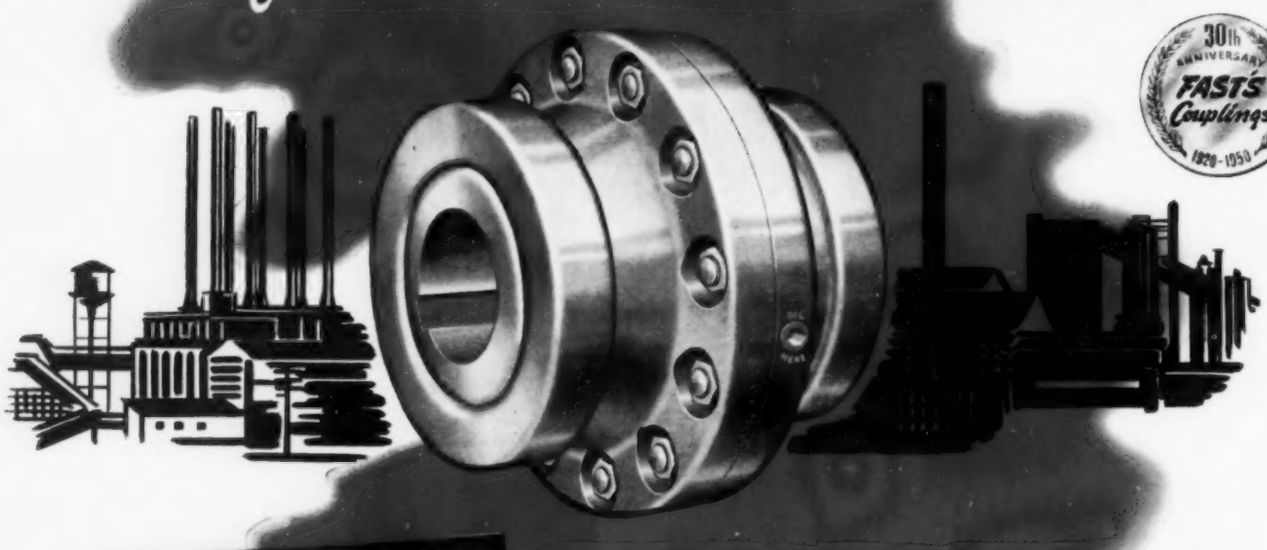
Major Heavy-duty, Steel Plant Air Dump Cars are available on the following terms:

1. By rental on long term lease
2. By rental with purchase option
3. On installment terms
4. By outright purchase

For full particulars, write — wire — phone

MAGOR CAR CORPORATION · 50 CHURCH ST., NEW YORK 7, N. Y.

you can FORGET COUPLING SHUTDOWNS—



INDUSTRY REPORTS—

KOPPERS ENGINEERING STOPS COSTLY FAILURES

In oil fields, steel mills, power plants . . . all through industry . . . cost-wise executives report that *Fast's Couplings,* designed, manufactured and guaranteed by Koppers, are the best insurance against coupling failures! Take a tip from these users who know. Specify Fast's and forget *your* coupling problems!

By specifying Fast's, you get the benefit of Koppers Engineering Service, acknowledged best in the industry. Koppers Engineers, backed by 30 years coupling experience, study your problem . . . then show you *which* Fast's Coupling fits your application, (and more important) *why* you need it!

Only Koppers can offer you this valuable service . . . only Koppers offers Fast's, the original gear-type coupling. Fast's Couplings assure you freedom from expensive coupling failures in your plant because Fast's have no perishable parts to fail!

GET THE FACTS: Mail coupon today for your free copy of the Fast's Coupling Catalog, published by Koppers. Shows how Fast's operate, describes the many sizes and types. Gives full details about Koppers Engineering Service. Send for your copy today.

These FAST'S COUPLING *Services save you money!*

UNSURPASSED ENGINEERING . . . *Koppers Engineers are acknowledged the best in the coupling industry. Their practical knowledge, backed by 30 years of coupling experience, is at your service!*

IMMEDIATE DELIVERY . . . *All standard types and sizes are available for immediate delivery from "on hand" stocks. In case of emergency, just wire factory for special rush delivery!*

LOWEST COST PER YEAR . . . *Fast's Couplings will outlast equipment they connect if properly maintained. Their cost may be spread out over 25 years or more, offering you lowest coupling cost per year!*

KOPPERS

FAST'S

THE ORIGINAL GEAR-TYPE

Couplings

FREE CATALOG

KOPPERS CO., INC., *Fast's Coupling Dept.,*
217 Scott Street, Baltimore 3, Md.

Please send me a free copy of your Fast's Coupling Catalog.

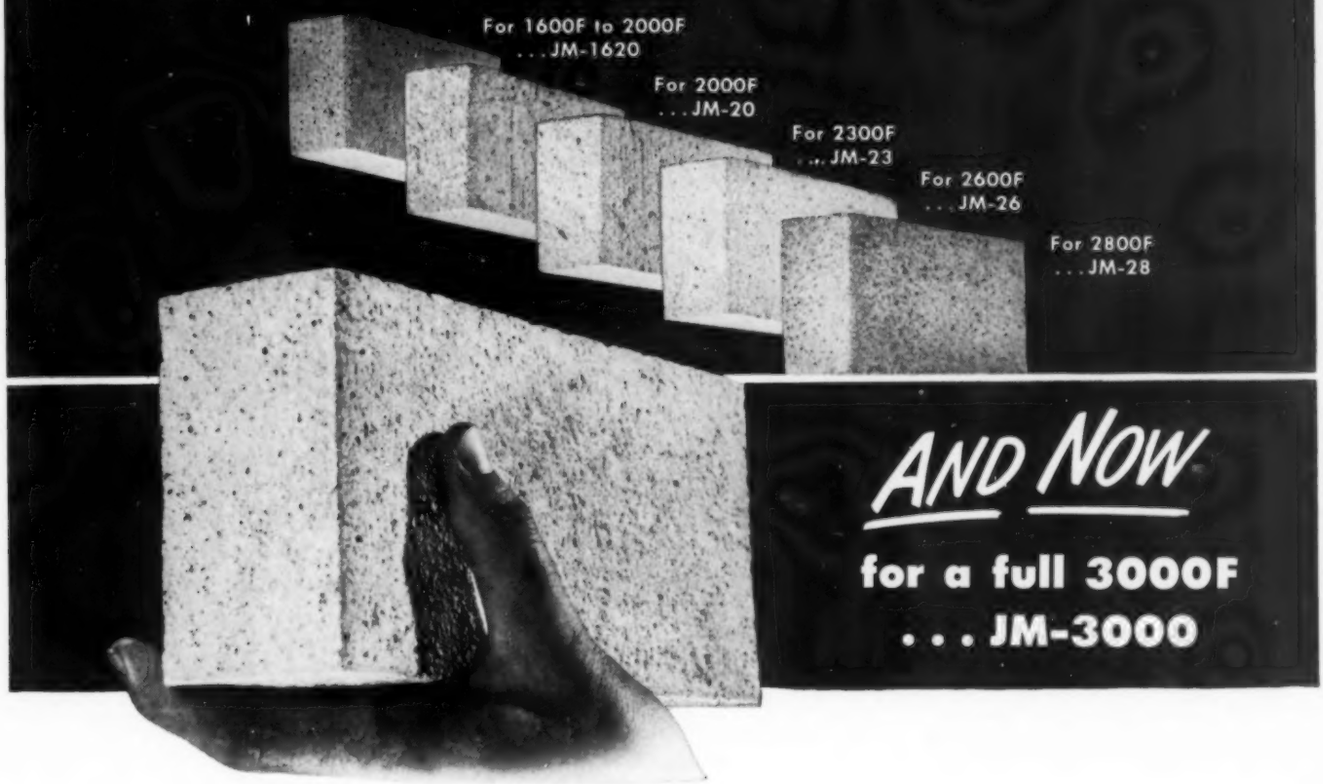
Name.....Title.....

Company.....

Address.....

City.....Zone.....State.....

MEET the family of Johns-Manville Insulating Fire Brick . .



HERE IS AN OUTSTANDING FAMILY of insulating fire brick for back-up or exposed use . . . the only family of its kind . . . that gives you a complete range . . . a *quick heating* insulating fire brick for every purpose.

By taking advantage of the quick heating characteristics of these insulating fire brick, you'll benefit through important savings in fuel because of the quicker rise to proper operating temperature in the furnace. This is a result of the low heat storage capacity and low thermal conductivity characteristics of the brick. These factors are especially important where furnaces are being intermittently operated.

The same materials can also be obtained in large size units as Johns-Manville Insulating Fireblok. This product has many advantages over the smaller size fire brick, from both a construction and stability standpoint. They can be quickly applied because they are easy to cut and fit. J-M Insulating Fireblok provide additional heat savings because they reduce the number of joints, and require less mortar for bonding.

Why not have a Johns-Manville insulation expert call to tell you more about ways in which you can save by using these insulations in your furnaces. Write Johns-Manville, Box 290, New York 16, N. Y. for further information.

	JM-1620	JM-20	JM-23	JM-26	JM-28	JM-3000
Densities, lb per cu ft	29	35	42	48	58	63-67
Transverse Strengths, psi	60	80	120	125	120	200
Cold Crushing Strengths, psi	70	115	170	190	150	400
Linear Shrinkage,† percent	0.0 at 2000 F	0.0 at 2000 F	0.3 at 2300 F	1.0 at 2600 F	4.0 at 2800 F	0.8 at 3000 F
Reversible Thermal Expansion, percent	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F
Conductivity* at Mean Temperatures						
500 F	0.77	0.97	1.51	1.92	2.00	3.10
1000 F	1.02	1.22	1.91	2.22	2.50	3.20
1500 F	1.27	1.47	2.31	2.52	3.00	3.35
2000 F	—	1.72	2.70	2.82	3.50	3.60
Recommended Service						
Back up	2000 F	2000 F	2300 F	2600 F	2800 F	3000 F
Exposed	1600 F	2000 F	2300 F	2600 F	2800 F	3000 F

† *24-hr simulative service panel test for JM-3000, 24-hr soaking period for other brick.*

* *Conductivity is expressed in Btu in. per sq ft per F per hour at the designated mean temperatures.*

Note: Above tests are in accordance with A.S.T.M. tentative standards.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville First in INSULATIONS

Modernization is a *Must!*

USE BILLETEERS!

Resounding hammer of the village blacksmith rings through early American industrial history. But would you trade your modern forging equipment for a brawny arm and a heavy sledge? *No! —Not for a whole battery of them!* In billet-cleaning, like forging, new methods pay handsomely. Here's how today's proven production of the Bonnot Billeteer stacks up against out-moded hand methods of billet-conditioning.

Engineered for Improved Production . . .

MANUAL CHIPPING	BILLETEER CONDITIONING
Labor costs high.	Labor costs reduced as much as 56%.
Slow, grueling operation.	Easy machine operation; does better work ten times faster.
Partial chip salvage.	Chips 100% recoverable.
Extremely hazardous.	Outstanding safety records such as 490,000 manhours with only one disabling accident.
Large inventory needed.	Minimum inventory and dependable, scheduled production.
Employee turnover high.	Fewer personal problems because men like to operate Billeteers.
Jitters and fatigue drastically limit span of worker's usefulness.	By contrast, rugged Billeteer stands the punishment—in many cases exceeding 100,000 hours of efficient performance, and with no absenteeism.

The Bonnot Co.
STEEL EQUIPMENT DIVISION
CANTON 2, OHIO

Let us show you how much the Bonnot Billeteer can save you in billet-conditioning and manpower costs — *Write today!*

ALSO MANUFACTURERS OF SAWING • CRUSHING • PULVERIZING & MIXING EQUIPMENT
—BILLET INSPECTION TABLES • BILLET SKID RAILS • SINTER PLANT PUG MILLS

ANOTHER QUALITY FEATURE IN...

ELLIOTT

FABRI-STEEL

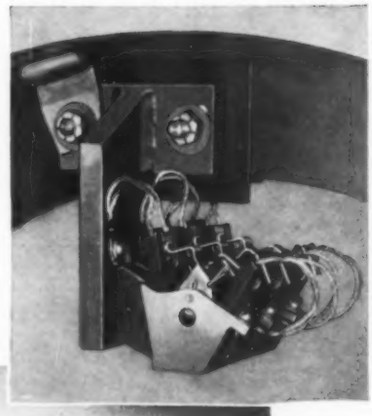
D-C MOTORS

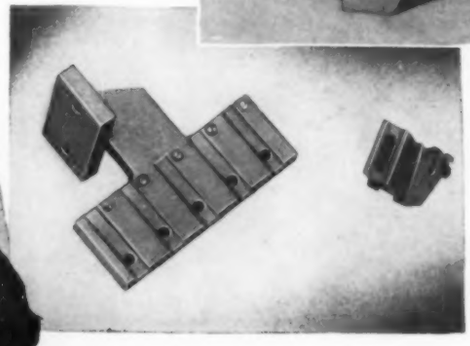
An exceptionally dependable, accurate and simple

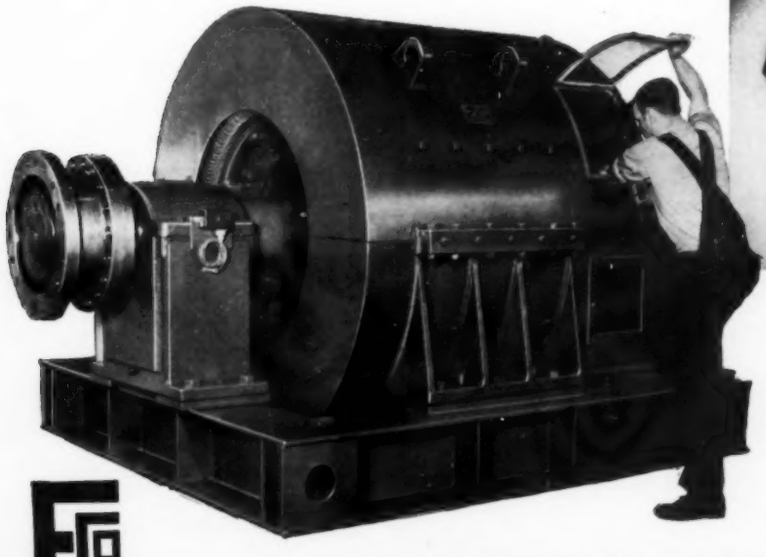
brush rigging

The brush yoke in Elliott DC Motors fits into frame supports bored concentric with the bore of the frame, assuring concentricity of yoke with frame and commutator. The brushholder bracket, machined to close tolerance, is fitted to the brush yoke, positioned with a special fixture for spacing and angle, then bolted and doweled to the brush yoke. Canvas phenolic plates, tubing and dowels provide insulation between bracket and yoke.

Each brushholder fits in a machined groove in the bracket. When the commutator wears, the loosening of one bolt in each brushholder permits it to be slid down its groove for correct clearance without affecting its original spacing or angular setting. Just one more of the numerous features that throughout the steel industry are making "Elliott Fabri-Steel" synonymous with forward-thinking motor and generator development.







Removable, hinged, quick-opening doors, of clear plastic, to get at commutator and brushes.

For full details on Elliott Fabri-Steel DC Motors, write to:

MR-5

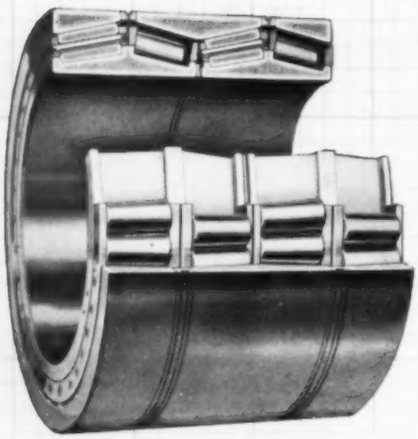
ELLIOTT COMPANY DEPT. I-5, RIDGWAY DIVISION RIDGWAY, PA.

Plants in JEANNETTE, PA., RIDGWAY, PA., AMPERE, N. J., SPRINGFIELD, OHIO, NEWARK, N. J.

DISTRICT OFFICES IN PRINCIPAL CITIES

more tons per turn...

TORRINGTON ROLL NECK BEARINGS



It takes bearings with rugged construction and sound metallurgy to keep roughing stands operating continually. In the rougher and other stands in Carnegie-Illinois Steel Corporation's 80" hot strip mill at Gary Sheet and Tin Mill, Torrington Roll Neck Bearings provide these and other advantages.

Four rows of tapered rollers provide high radial and thrust capacity. The reduced cross-section of these bearings allows larger roll necks for maximum rigidity. Minimum friction allows rapid acceleration with improved quality and uniformity of gage of sheet.

These Torrington Roll Neck Bearing features add up to economical operation, greater production and lower maintenance. Specify Torrington Bearings for your mill stands and auxiliary equipment.

THE TORRINGTON COMPANY
South Bend 21, Ind. • Torrington, Conn.
District Offices and Distributors in Principal Cities
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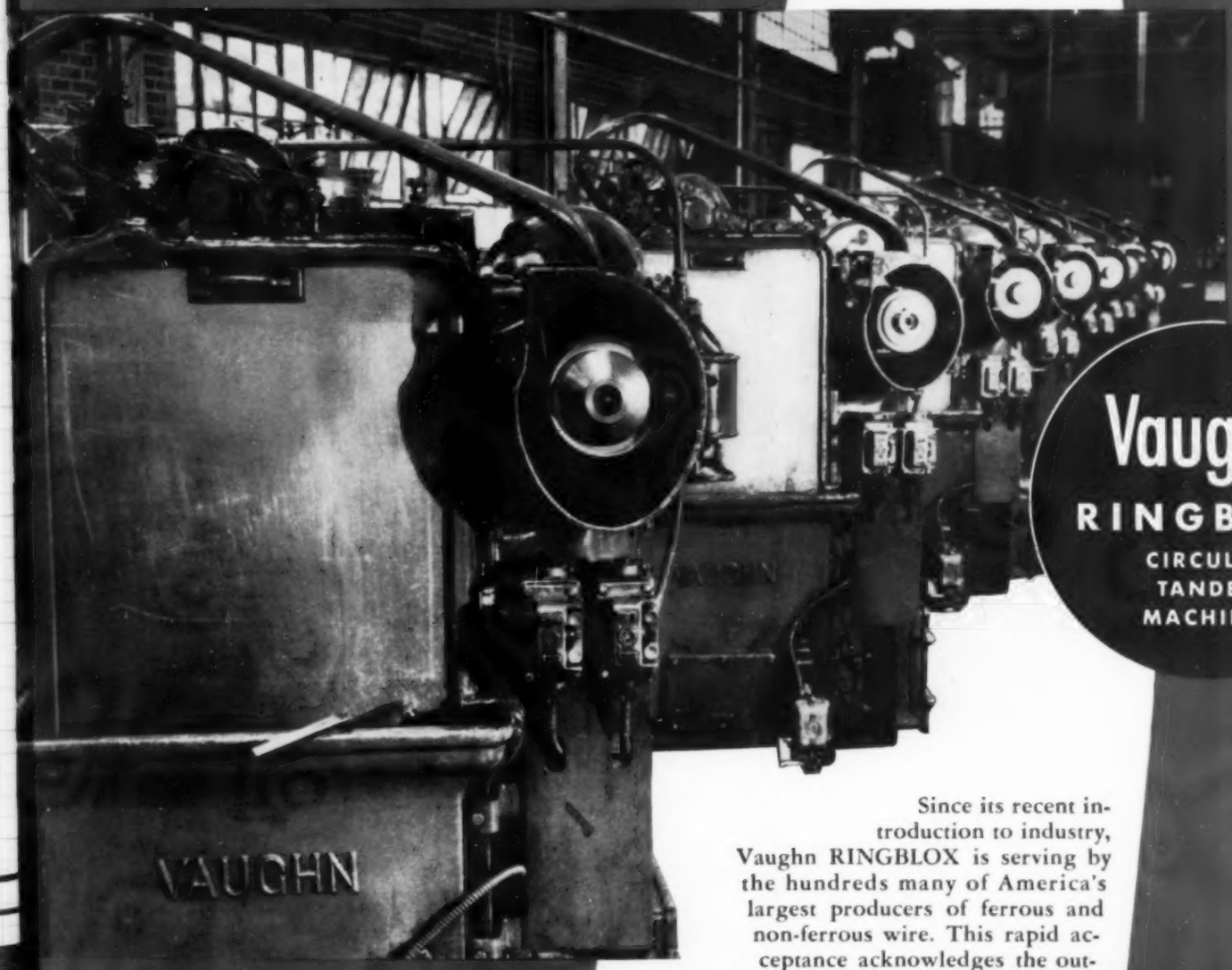
TORRINGTON *TAPERED ROLLER* BEARINGS

SPHERICAL ROLLER TAPERED ROLLER • STRAIGHT ROLLER • NEEDLE • BALL • NEEDLE ROLLERS

Wire V intermediate, fine and very fine

—at high rates of speed



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RINGBLOX
CIRCULAR
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An 8-unit installation of Vaughn RINGBLOX at the Massena, N.Y. plant of Aluminum Company of America.

Since its recent introduction to industry, Vaughn RINGBLOX is serving by the hundreds many of America's largest producers of ferrous and non-ferrous wire. This rapid acceptance acknowledges the outstanding ability of RINGBLOX in speeding production through higher operating efficiency.

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COMPLETE COLD DRAWING EQUIPMENT—Continuous or Single Hole . . . for the Largest Bars and Tubes . . . for the Smallest Wire . . . Ferrous, Non-Ferrous Materials or their Alloys

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VAUGHN MACHINERY
Profitably Used by Leading Wire Mills Since 1871

FOR OVER FORTY YEARS

THE BEST GEARS MONEY CAN BUY

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REG. T. M.

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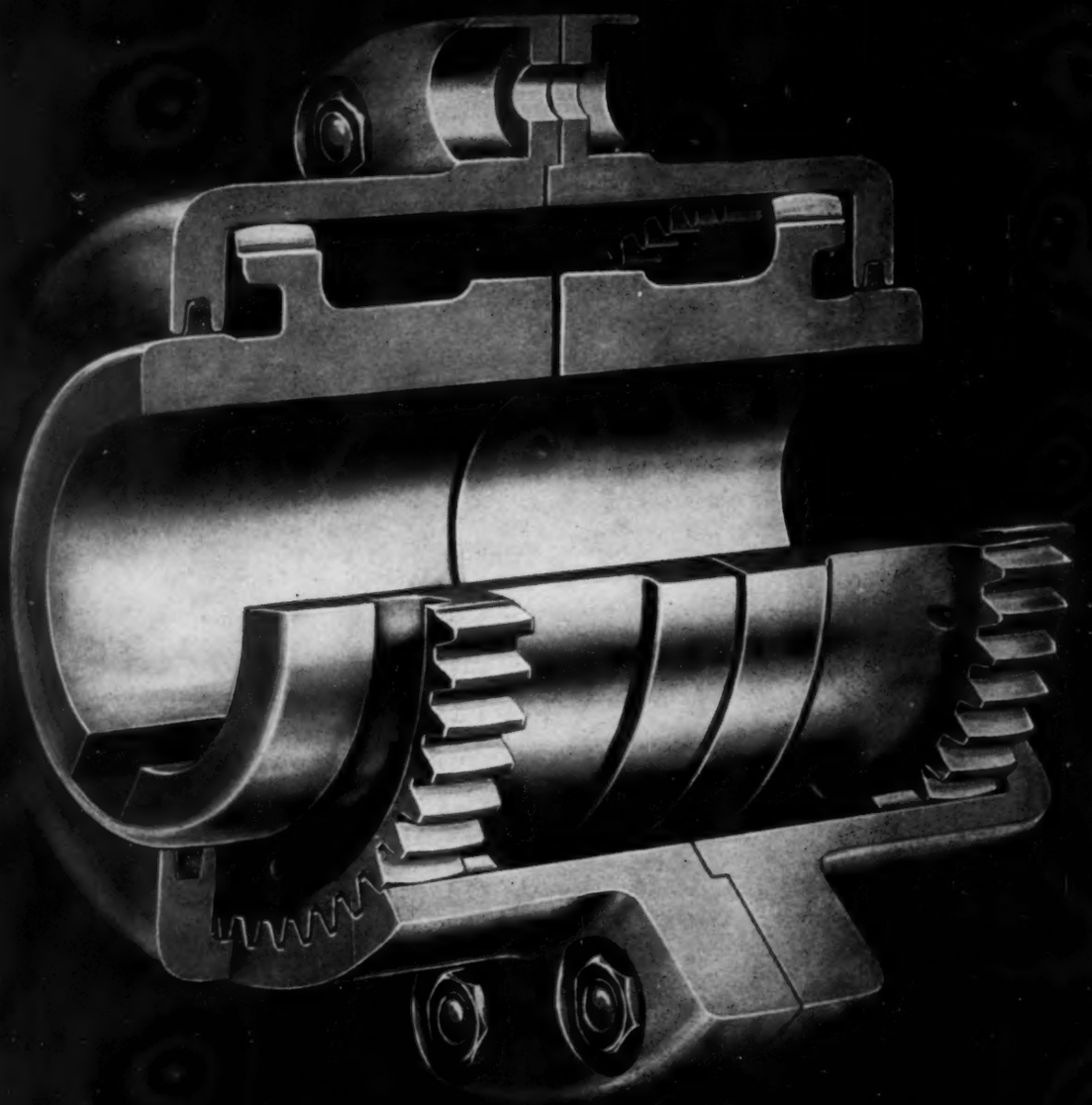
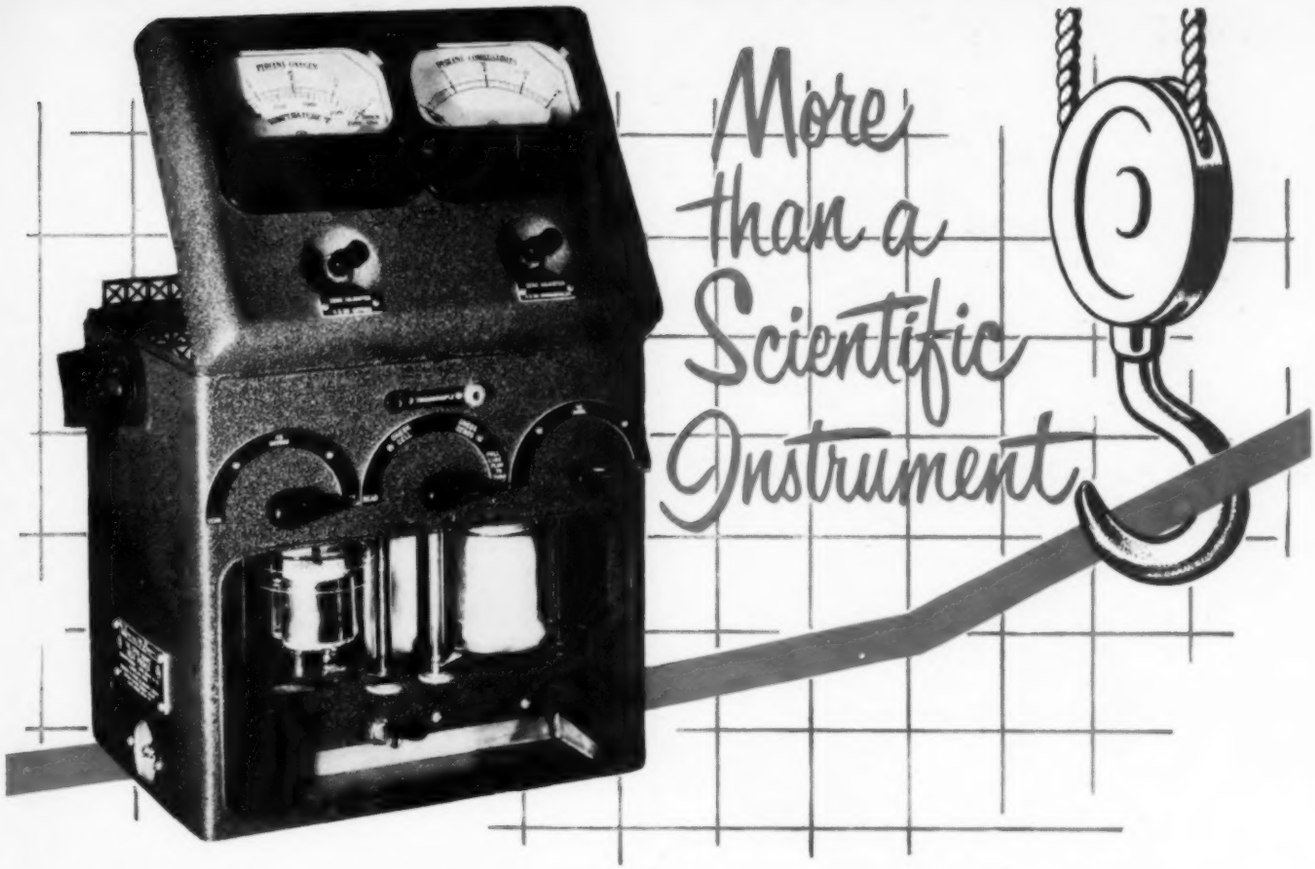


A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY WOODBERRY, BALTIMORE, MD.



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Are you wasting furnace fuel? ☐

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Facts that answer these vital questions are promptly supplied by the Cities Service Heat Prover. This exclusive flue gas analyzer strictly checks combustion factors. Then sources of loss can be traced and corrected. Operators of all types of furnaces report they have been able to clamp down on cost and step up production, simply by using the Cities Service Heat Prover. Find out how easily you can arrange to put it on the job. Send the coupon.

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- ★ Chillo Cutting Oils
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⇩ This coupon brings complete details in your copy of "Combustion Control for Industry."

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For maximum production . . . top efficiency . . . lowest operating cost, give your machines the finest in lubricants—give them Tycol oils and greases.

Tycol lubricants are made to meet every lubrication need of industry—from roll neck greases for steel mills to spindle oils for textile plants.

Each Tycol lubricant is subjected to rigid tests during manufacture. This control assures the required lubrication characteristics—*COLOR, penetration, viscosity, to name a few—for maximum performance of that particular product. At every step from selection of crudes to blending of the finished product, Tycol lubricants provide maximum lubricating efficiency which means greater economy, longer life for every type of equipment.

Tide Water Associated will be glad to assist you in selecting the Tycol lubricant best suited to your specific need. Call or write your nearest office for further details.

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LINK-BELT
Ball and Roller Bearings are "HOUSING SEALED" Completely...

to assure free aligning action

The aligning surfaces are completely enclosed within the lubricant area of the bearing. The seals maintain their high effectiveness regardless of alignment.

to keep out dirt and moisture

The lubricated seals keep grease in and dirt and moisture out, even under extreme misalignment, contributing to longer life of bearing.

to reduce wear under most severe conditions

The exclusion of dirt and moisture and the retention of lubricant *within* the "housing sealed" area, assure minimum wear even under severe operating conditions.

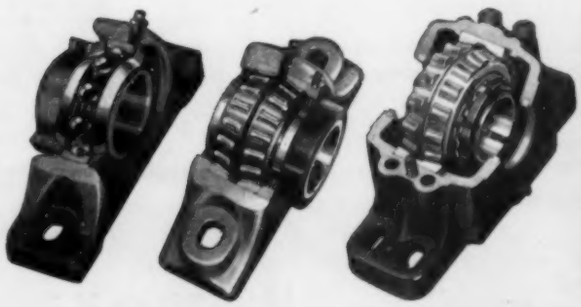
Link-Belt engineers with broad experience in power transmission and bearing application will be pleased to consult with you without obligation. May we send you Data Book No. 2550 containing full engineering information?

THE SYMBOL OF QUALITY — LB — LINK-BELT

LINK-BELT COMPANY Indianapolis 6, Chicago 9, Philadelphia 40, Atlanta, Minneapolis 5, Houston 1, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8. Offices, Factory Branch Stores and Distributors in Principal Cities.

11,790

A complete line of bearings is available from stock, throughout the country, in pillow blocks, cartridge, flanged cartridge, flanged, hanger and takeup blocks —also unmounted bearings.



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BALL & ROLLER

BEARINGS

Equip your cranes with Wagner "Full Control" Hydraulic Bridge Brakes

Hydraulic brakes have proved to be the best brakes available to bring overhead traveling cranes to safe, sure stops. Hydraulic brakes for the bridge drives of electric overhead traveling cranes are included in AISE Specifications. Play safe . . . equip your cranes with Wagner Hydraulic Crane Bridge Brakes and give your operators "full control" at all times for close spotting and smooth deceleration.

* * *

Only WAGNER Hydraulic Crane-Bridge Brakes give you all these features:

A Size and Type for Every Application . . .

Two types, with or without parking attachment, and four sizes are capable of handling any application.

Remote Control Bleeder . . .

Keeps lines full of fluid, maintains peak braking efficiency, and makes bleeding the system an easy, "one-man" job.

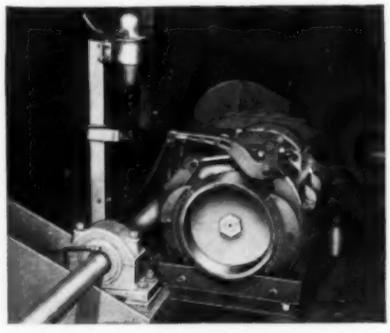
Self-Centering Device . . .

Prevent brake shoe drag by assuring equal clearance of both brake shoes.

Other Advantages Include . . .

Power failure braking . . . one-point shoe adjustment . . . 200% emergency torque . . . grease fittings for lubrication . . . non-scoring, easily replaceable molded lining blocks.

If your cranes are not equipped with Wagner brakes, one of our field engineers will gladly show you how simple it is to install a modern hydraulic system. If you now have Wagner brakes, your system can be quickly modernized with our complete conversion kits . . . Bulletin IU-40 gives full information—write for copy.



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WAGNER ELECTRIC CORPORATION
6483 Plymouth Ave., St. Louis 14, Mo., U.S.A.

ELECTRIC MOTORS • TRANSFORMERS • INDUSTRIAL BRAKES
AUTOMOTIVE BRAKE SYSTEMS – AIR AND HYDRAULIC

BRANCHES IN 31 PRINCIPAL CITIES

Up to 22 times
more operations without re-lubricating

HOMESTEAD-REISER
Self-Sealed
LUBRICATED PLUG
VALVES

TEST RECORD

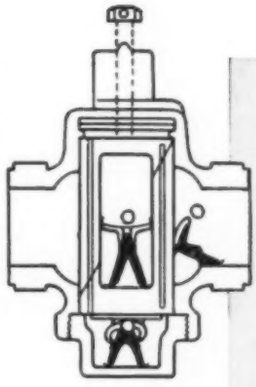
VALVE	NO. OF OPERATIONS Without RE-LUBRICATING
VALVE "A"	5
VALVE "B"	33
HOMESTEAD-REISER VALVE	**110**

Each valve assembled with the manufacturer's recommended lubricant. Test made on 75 lb. air pressure.

This comparative test of a Homestead-Reiser Valve and two other well-known lubricated plug valves showed that the Homestead-Reiser Valve remained drop-tight through twenty-two times more operations than Valve "A" without re-lubricating, and through three times as many operations as Valve "B". That means that Homestead-Reisers require less attention, and give greater economy of lubricant.

Prove the superiority of Homestead-Reiser Valves to your own satisfaction, by installing a few in your plant, side by side with any other lubricated plug valve. They may be had in both semi-steel and cast-steel, sizes ½" to 12" for steam working pressures to 150 pounds, or oil-water-gas to 200 pounds.

Write for new catalog 39-5, and for prices on your requirements.



"Self-Sealed" MEANS

. . . that in addition to a full-port lubricant seal, the wedge-action of the plug under line pressure forces the finished surfaces of the plug outward, and constantly presses them against the seating surfaces of the body, thus keeping them always in intimate contact. The plug automatically adjusts itself for wear, assuring extra long life, maximum leakless service, and lubricant economy.

HOMESTEAD VALVE MANUFACTURING CO.
"Serving Since 1892"

P. O. Box 21 **CORAOPOLIS, PA.**

So—We Sold Them the Pilot Model of Our New FT (100% Functional) Fork Truck which Had Been in Their Plant on Test

Put yourself in our place. Our engineers had been instructed to design a new 3000 to 4000 lb. capacity electric fork truck—a completely functional *"work horse"*—retaining traditional Baker quality and ruggedness and adding features that contribute to greater utility, safety and convenience.

For months they worked like demons—analyzing basic materials, testing controls, motor characteristics, hydraulic equipment, studying every essential truck function, designing, re-designing, assembling, re-assembling.

Finally they said—"HERE IT IS!"

"Looks like a lot of truck," said our management, "but how much will it cost?"

"LESS THAN ANY TRUCK IN ITS CLASS!" was the answer.

"Will it do the job?"

"LOOK AT THESE TEST RECORDS!"

Our engineers had subjected this truck to exhaustive tests covering every conceivable truck function. It had come through with flying colors.

BUT WE WANTED TO BE SURE!

So we selected a plant which had just about the toughest operating conditions you'll find anywhere, and put one of the pilot models on test there.

This plant is a high-production foundry. Abrasive dust, heavy, punishing loads, typical foundry floor conditions, continuous, round-the-clock, three-shift operation—the most strenuous service you'll ever ask of a truck.

Frankly, no industrial truck had ever been able to "stand the gaff" in this foundry.

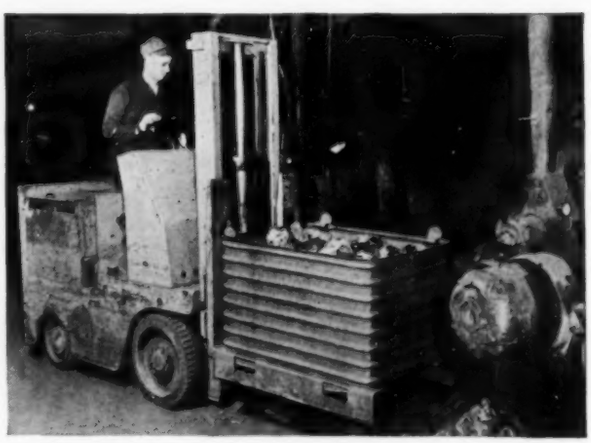
BUT THE BAKER FT DID!

From the day it was installed, there was NOT ONE MINUTE OF DOWN TIME!

As a result, the company insisted on keeping *this truck:* the pilot model which was in their plant on test!

●

That's the story of the development of the new Baker FT 3000 to 4000 lb. capacity Electric Fork Truck. Production models are now rolling off the assembly line in our new modern plant. Write us, or ask your nearest Baker representative to give you details on the toughest, lowest-priced, fork truck in its class.



Baker FT Fork Truck delivering rough castings to tumbling machine at the Taylor & Boggis Foundry.

THE BAKER INDUSTRIAL TRUCK DIVISION *of The Baker-Raulang Co.*
1229 WEST 80TH STREET • CLEVELAND 2, OHIO
In Canada: Railway and Power Engineering Corporation, Ltd.

STOP RUST!

YOU can STOP RUST . . . PREVENT RUST...on *any* rustable metal surface with RUST-OLEUM. Every day, rust eats away on your metal tanks, buildings, fences, stairs...everything metal inside and outside your plant. Yet, rust *can* be stopped and protection given economically with RUST-OLEUM.

For more than a quarter of a century RUST-OLEUM has been *proved* under severe conditions of weather, fumes, salt air, salt spray, and other rust producing conditions. Railroads, shipyards, builders, refiners...nationally known users* in almost every field of industry...have found RUST-OLEUM the economical way to stop rust and prevent further rust. Architects, builders, engineers, maintenance men now specify RUST-OLEUM for primer, "shop coat", and finish coats.

RUST-OLEUM adds extra life to metal buildings, equipment and other metal surfaces and can be applied over already rusted surfaces without extensive surface preparation. Yet, RUST-OLEUM costs no more than most quality materials.

RUST-OLEUM not only protects — it beautifies as well! RUST-OLEUM is available in a large selection of colors including aluminum and white. It spreads evenly...and dries free of brushmarks in 4 to 12 hours, depending on conditions, to a tough, pliable film that protects against rust.

Be sure you get *only* genuine RUST-OLEUM for positive protection against rust! Specify RUST-OLEUM to your contractor or architect on any new construction, remodeling or maintenance work.

RUST-OLEUM is stocked and sold by leading industrial distributors in all principal cities of the United States and Canada. See Sweets for complete catalog and nearest source of supply, or write us direct for complete information.

**Names on request*

RUST-OLEUM CORPORATION

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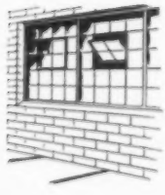
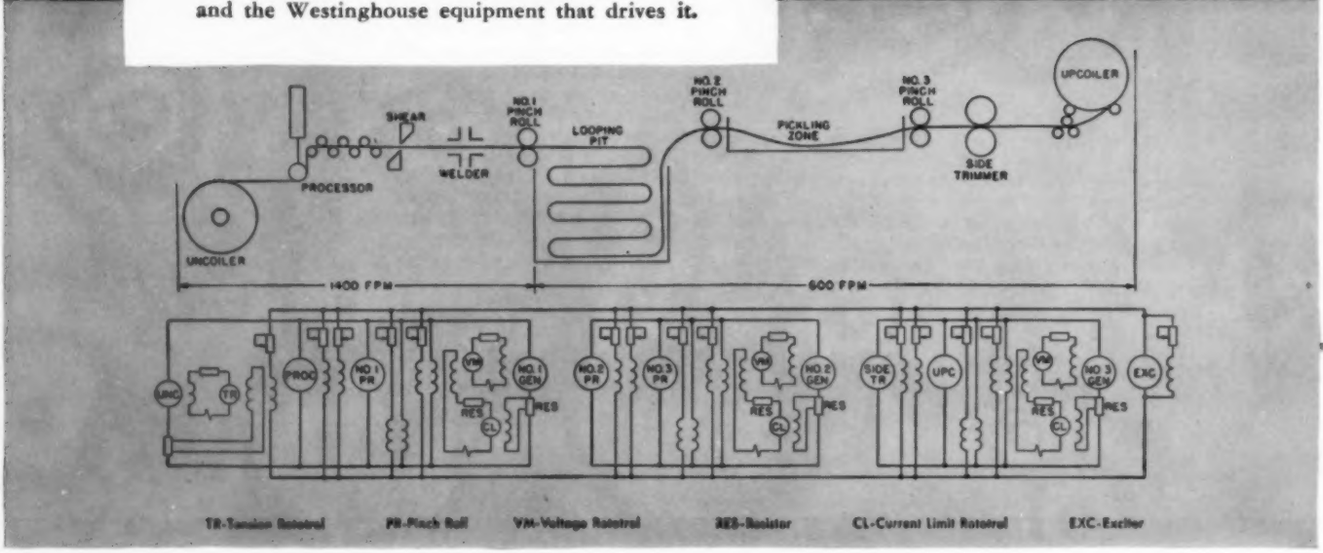


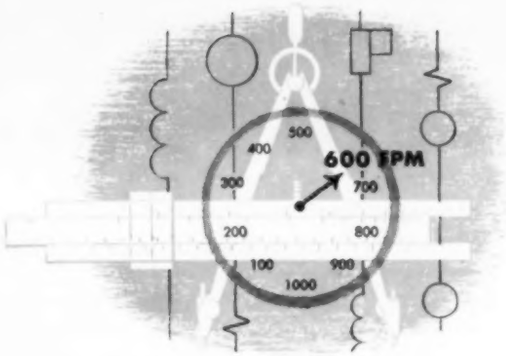
YOU CAN BE **SURE**.. IF IT'S
Westinghouse

Looping pit in the world's fastest strip pickling line, and shown beyond it, the pickling tanks.

• • •

Simplified schematic drawing of the pickling line and the Westinghouse equipment that drives it.





The world's fastest strip pickler

CAN YOUR NEXT JOB USE THE KNOW-HOW THAT ENGINEERED ITS ELECTRIC DRIVE?

You may not be considering strip pickling lines right now. But the know-how that engineered the drive for this one *can* make your next installation a better one, whatever it may be. Here's how it met this problem.

The mill wanted a line to turn out 50,000 tons per month in 30,000-lb. coils. That meant an exit speed around 600 fpm, *20% faster than any other line in existence.* Four or five hot-rolled coils would be fed in for each emerging coil. So to allow for time required in shearing, welding, and trimming the ends, the entry speed had to be 1400 fpm.

So these were the basic requirements: 1. Build a drive that keeps speed *constant* in the pickling zone to keep quality uniform. 2. Maintain constant rates of *acceleration and deceleration* in the entry side so that a high-production, continuous operating cycle could be established. 3. Provide *fast* acceleration and deceleration to minimize idle time at the entry end.

Westinghouse answered the needs with a three-stage adjustable-voltage drive regulated by ROTOTROL, the master electrical intelligence. The first-stage motors, supplied by one M-G set, drive the uncoiler, scale-breaker, shear, welder, trimmer, and pinch roll—the strip passing through each in turn. Strip then enters the looping pit. The second-stage motors, supplied by a second M-G set, drive the pinch rolls on either side of the pickle tank. The third stage drives the exit end of the line: a second shear, side trimmer, oiling rolls and final coiler.

The three-stage drive gives the needed speed differential AND speed control. Moreover the line is easy to operate since all operations, including shearing, welding, and trimming are at least semiautomatic.

It took the combined efforts of the mill, the equipment builders and Westinghouse to engineer this line. The electric drive is a result of this company's lifetime of intimate contact with the steel industry. And it can pay off on your next job. Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pa. J-94845

Westinghouse

EQUIPMENT FOR THE STEEL INDUSTRY

Aetna-Standard piercing mill...

Does its hole job on TIMKEN® bearings

TO carry the heavy loads of the piercing operation, this Aetna-Standard piercing mill is equipped with Timken® bearings on the 4500 h.p. gear drive, on the main rolls and in the thrust block. Timken bearings permit acceleration from a stop to high speed in a few seconds, take radial and thrust loads in any combination and reduce maintenance to a minimum.

Line contact between the rollers and races of Timken tapered roller bearings provides maximum load-carrying capacity. Shafts are held in positive alignment, providing accurate gear-meshing and reducing wear. And because Timken bearings are manufactured to extreme precision and finished to incredible smoothness, Timken bearings virtually eliminate friction. Tighter closures are permitted and lubricants are more effectively retained.

Timken bearings have exceptionally long life because they are (1) engineered for the job, (2) are made of Timken fine alloy steel, (3) are precision manufactured.

More than half a century of bearing research and development have made Timken bearings first choice throughout industry. No other bearing gives you *all* the advantages you get with Timken bearings. Whether you buy or build machinery, look for the trademark "Timken" on the bearings. The Timken Roller Bearing Company, Canton 6, Ohio. Cable address: "TIMROSCO".

This symbol on a product means its bearings are the best.

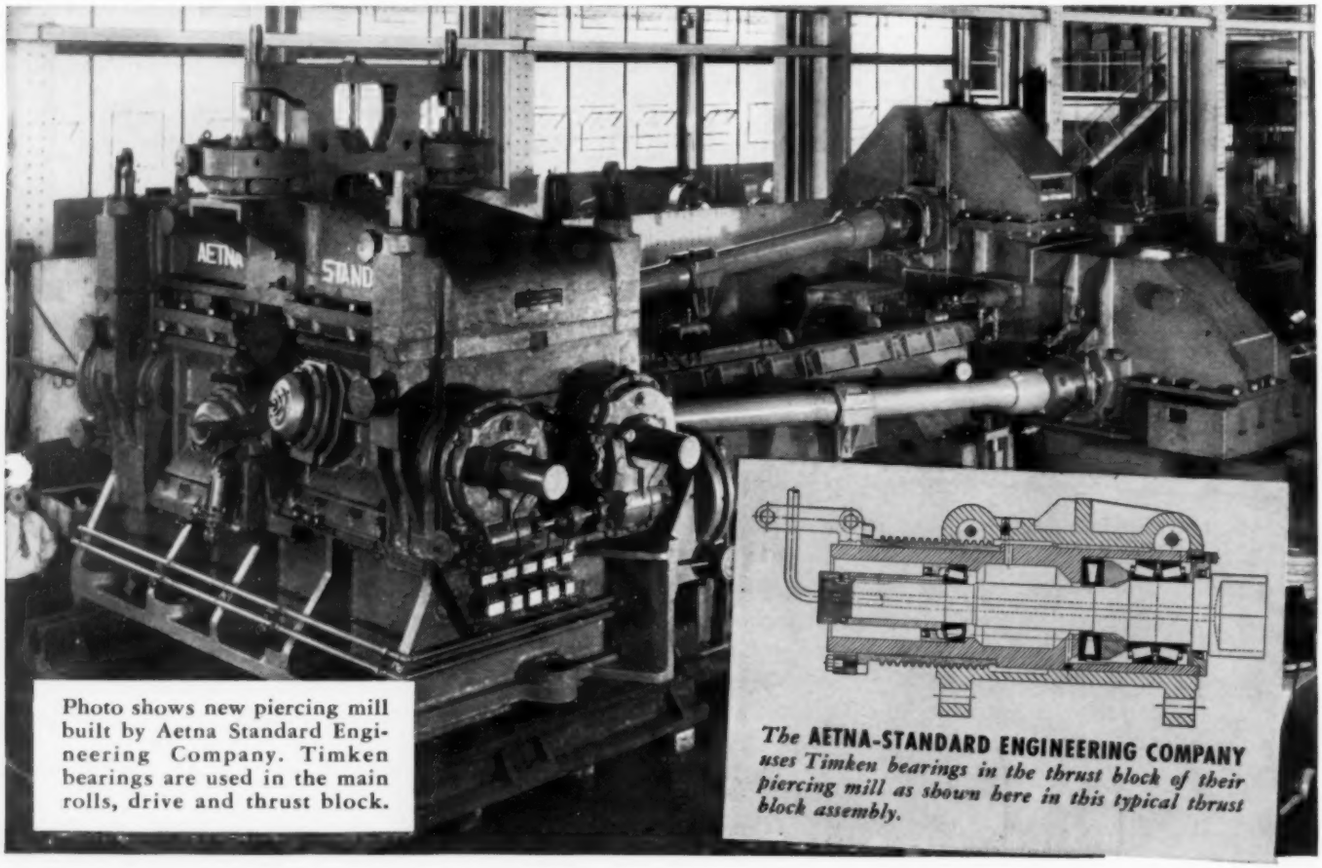
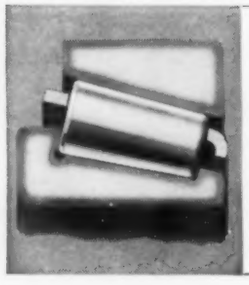


Photo shows new piercing mill built by Aetna Standard Engineering Company. Timken bearings are used in the main rolls, drive and thrust block.

The **AETNA-STANDARD ENGINEERING COMPANY** *uses Timken bearings in the thrust block of their piercing mill as shown here in this typical thrust block assembly.*



GREATER LOAD AREA

Because the load is carried on the *line* of contact between rollers and races, Timken bearings carry greater loads, hold shafts in line, wear longer.

The Timken Roller Bearing Company is the acknowledged leader in: 1. advanced design; 2. precision manufacturing; 3. rigid quality control; 4. special analysis steels.

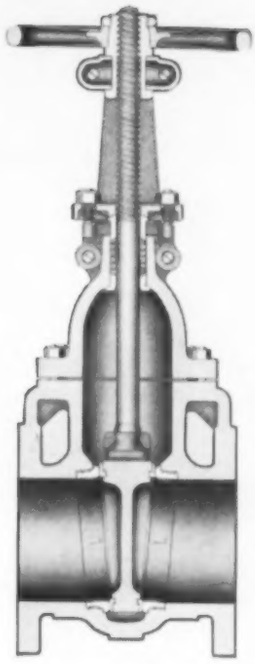
TIMKEN

TRADE-MARK REG. U. S. PAT. OFF.

TAPERED ROLLER BEARINGS

NOT JUST A BALL NOT JUST A ROLLER THE TIMKEN TAPERED ROLLER BEARING TAKES RADIAL AND THRUST LOADS OR ANY COMBINATION

For quality in every piping item ... Get <u>everything</u> from CRANE



Cross-Section No. 465½, Flanged Gate. Sizes: 2 to 12-in. Working Pressures: 125 pounds steam; up to 200 pounds water, oil, gas. Brass trimmed or all-iron. Larger sizes up to 48-in.

BUILT TO STAY IN SERVICE LONGER

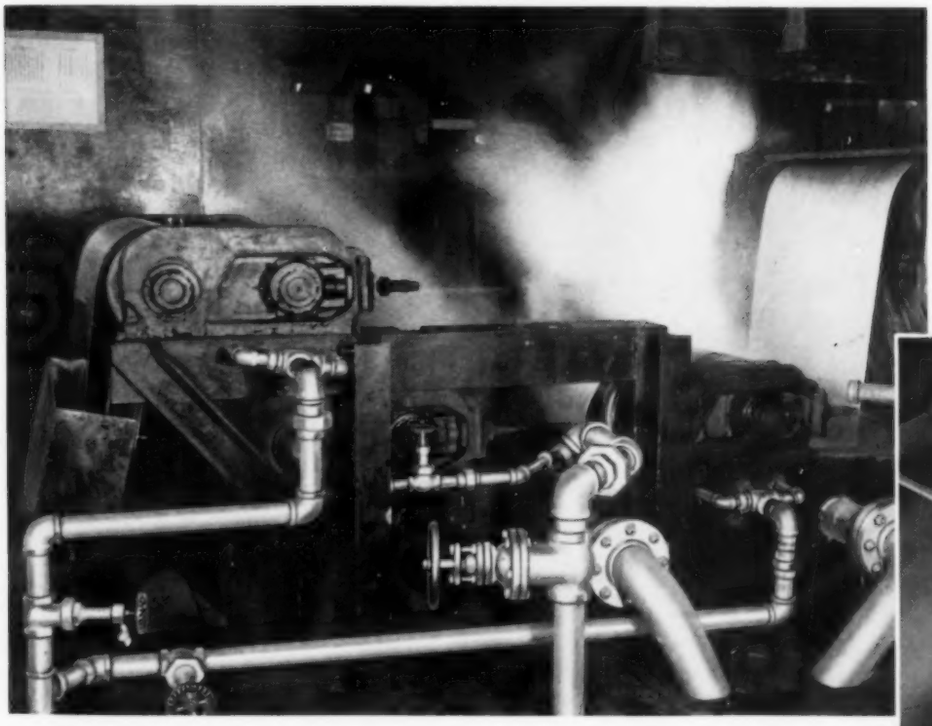
Fact is, these Crane 125-Pound Iron Body Gates—ruggedly constructed of finest quality materials—not only last longer, but require the minimum of routine servicing.

Stuffing box, extra deep and filled with high grade packing, maintains a tight stem seal and increases life of packing. Note the body-bonnet joint. Husky flanges use a greater number of bolts to equalize pressure on gasket. Body seat rings are renewable, do not loosen in service.

You'll find these valves easy to operate. Disc is guided to assure smooth, accurate seating. Crane disc-stem connection and two-piece ball-type gland prevent side strain on stem and binding of working parts. See your No. 49 Crane Catalog.

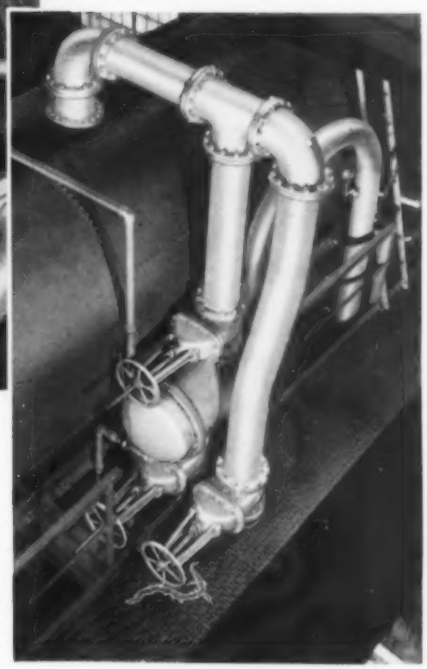
CRANE CO., 836 S. Michigan Ave., Chicago 5, Ill.
Branches and Wholesalers Serving All Industrial Areas

● ***FOR A MORE COMPLETE SELECTION OF VALVES, FITTINGS, PIPE AND ACCESSORIES . . . CHECK THE CRANE LINE***



ELECTROLYTIC UNIT *in a tin mill, equipped with Crane brass and iron valves, unions, flanged and screwed fittings.*

FEED WATER CONDENSATE *storage tank lines featuring Crane iron gate valves and flanged fittings.*

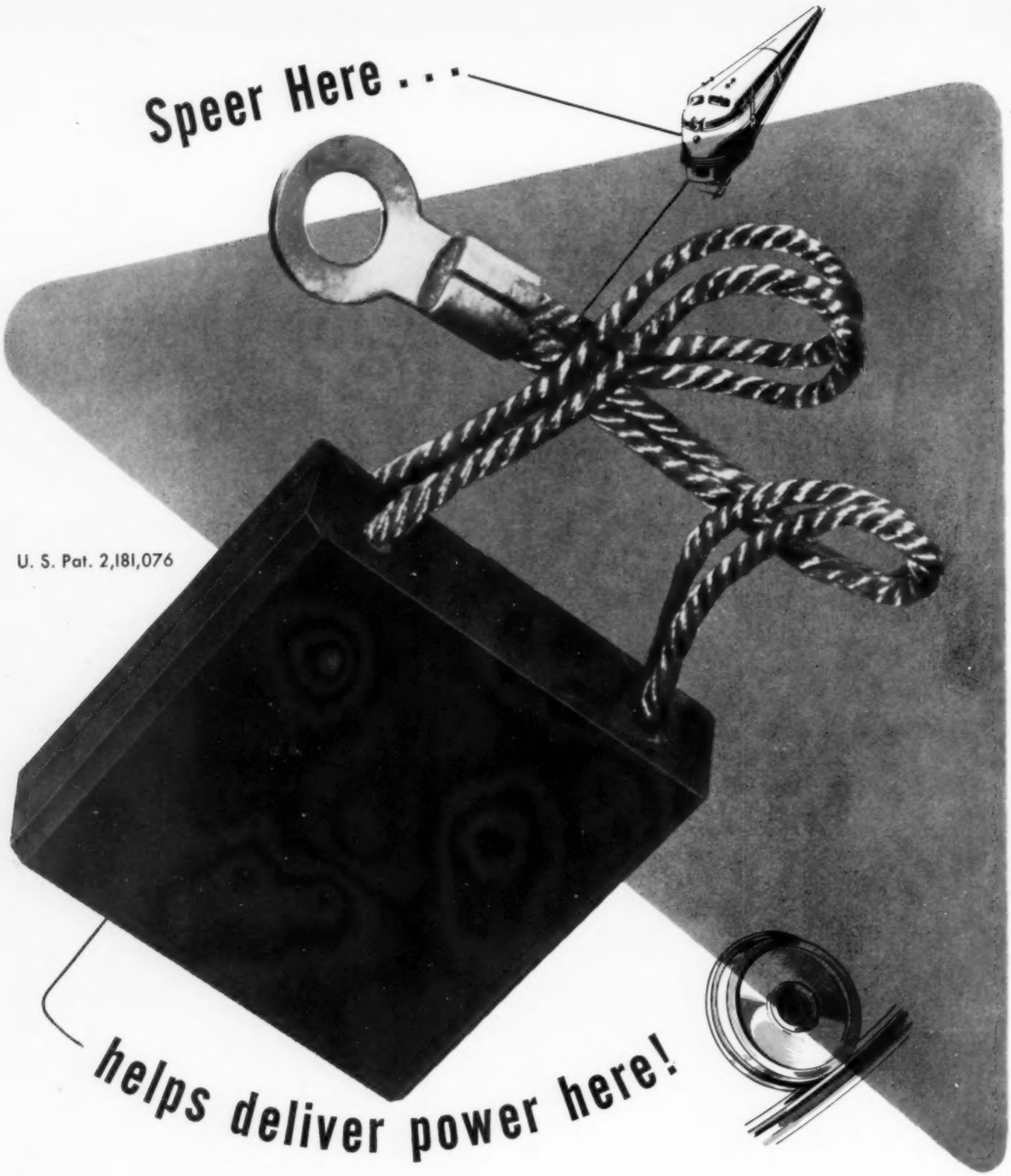


EVERYTHING FOR EVERY PIPING SYSTEM

CRANE

VALVES • FITTINGS • PIPE • PLUMBING AND HEATING

Speer Here . . .



U. S. Pat. 2,181,076

helps deliver power here!

High tractive efforts . . . sustained brute tonnages . . . impose super brush requirements on the generators and traction motors of today's Diesel Electrics.

Speer carbon brushes reflect the latest engineering advances and represent years of manufacturing experience . . . "Service" designed to meet all industry requirements.

If you have a "brush" design or maintenance problem why not take advantage of Speer's complete laboratory facilities? Write us, today.

SPEER

Speer

CARBON COMPANY
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6435

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FIRST IN SIZE
FIRST IN CRANE DESIGN

● We produce big and unusual cranes. We're delighted with unheard of and almost impossible applications for cranes. For example, above is a 270-ton gantry crane installed fifteen years ago on this dam. Successful operation of the dam depends on the crane. Similarly, other huge installations depend on **big Alliance cranes.**

On this crane two 135-ton trolleys can act independently or in combination when lifting loads in excess of 135 tons. One trolley is equipped with a 20-ton auxiliary hoist to handle lighter loads.

For fifty years, Alliance has been designing, engineering and building giant cranes for heavy industry. Where unusual types of cranes are required—for any service—Alliance engineering experience and diversified background of its personnel is generally sought.

Thousands of Alliance cranes are on the job today hoisting and shifting gigantic loads . . . safely, smoothly, quickly, economically. Always rely on Alliance to give your plant dependable extra lifting power.

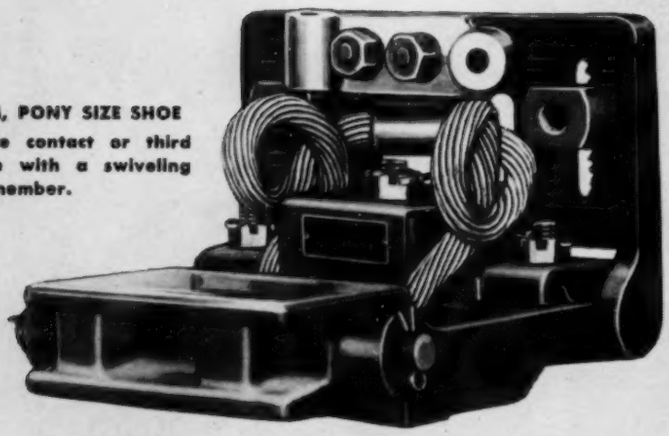
BIG
CRANES

THE ALLIANCE MACHINE COMPANY

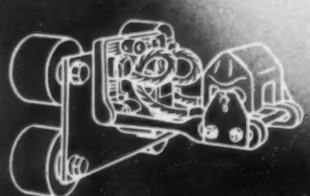
MAIN OFFICE
ALLIANCE, OHIO • PITTSBURGH OFFICE **1622 OLIVER BUILDING, PITTSBURGH, PA.**

LADLE CRANES • GANTRY CRANES • FORGING MANIPULATORS • SOAKING PIT CRANES • STRIPPER CRANES • SLAB AND BILLET CHARGING MACHINES • OPEN HEARTH CHARGING MACHINES • SPECIAL MILL MACHINERY • STRUCTURAL FABRICATION

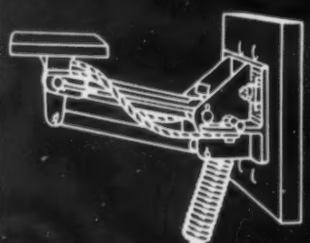
CONTINUOUSLY CONTACTS MAXIMUM RAIL AREA



TYPE LM, PONY SIZE SHOE
Reversible contact or third rail shoe with a swiveling contact member.



TYPE LMV SPECIAL SHOE
Four insulators; 2" horizontal movement. Other types of special contact shoes also available.



TYPE PS UNDER-RUNNING SHOE
For under-running service. Contact surface approximately 9" wide, 9" long.

KEYSTONE RAIL SHOES PROVIDE CONSTANT CONTACT

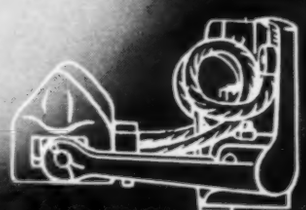
Want a shoe that maintains constant contact with the conductor despite rail misalignments? Want shoes that are reversible? Then Keystone Contact Rail Shoes are the ones to specify.

. . . *constant contact!* A strong spring keeps the swiveled contact member under pressure and assures perfect meeting with the rail . . . even on rails out of alignment. Adjust one bolt and spring pressure is regulated.

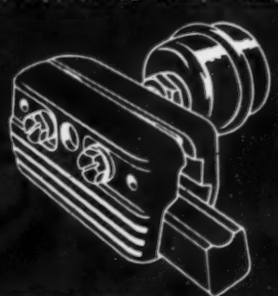
. . . *reversible shoes!* Over-running or under-running service is possible . . . simply reverse the position of the contact member and the compressor spring.

. . . *flexible cables!* Flexible copper connection cables link the upper bronze connecting block direct to the contact member. The design of the cable terminal lug allows feeder cables to enter the top or the side.

There is a Keystone Contact Rail Shoe to meet every requirement of steel mills. For complete information write for "Keystone Industrial Products."



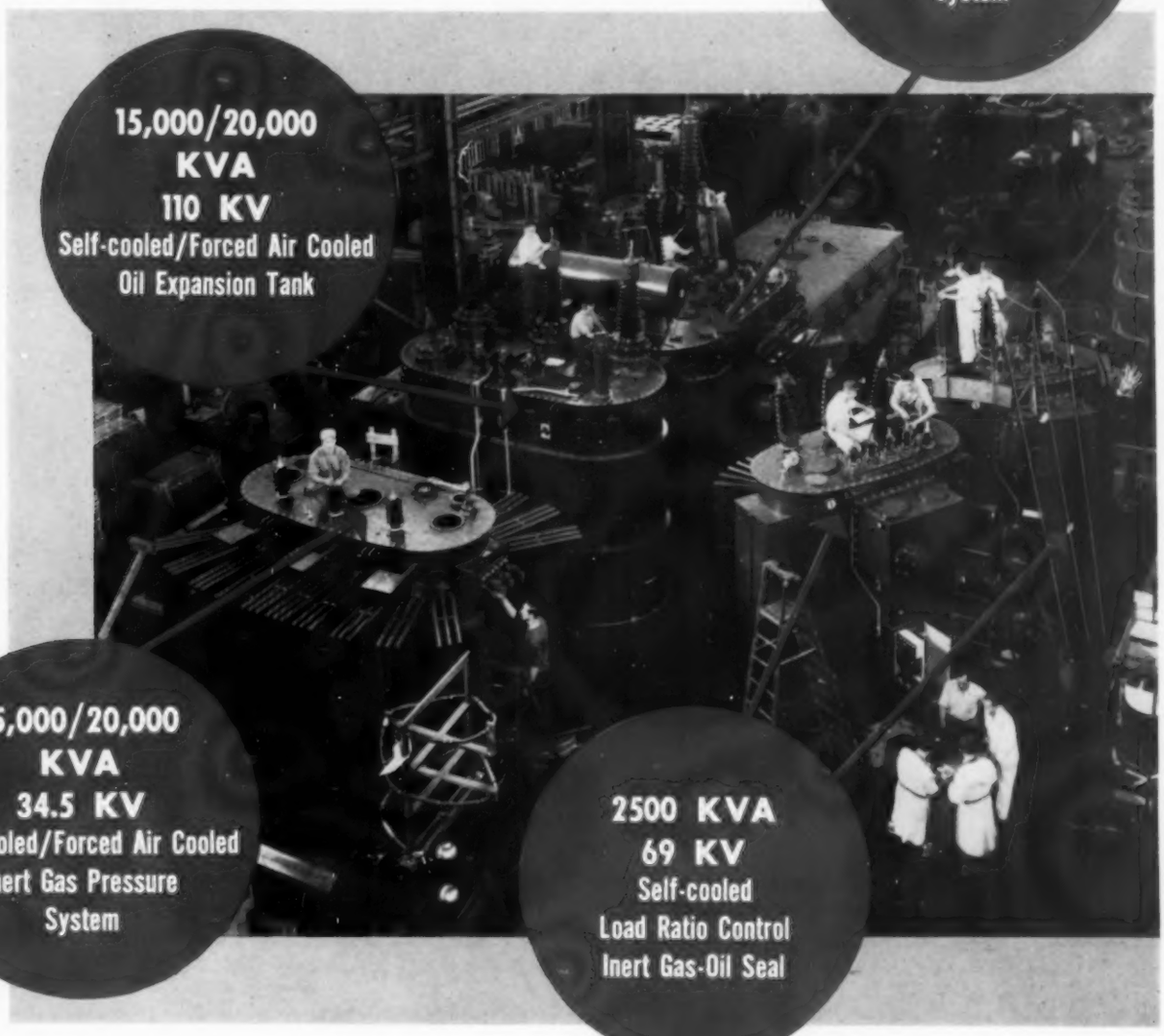
TYPE LMV, PONY SIZE SHOE
For V 2" x 2" angle iron contact rails. Two contact surfaces, each 1½" wide, 5" long.



TYPE BI PICK-UP COLLECTOR
For wire conductors. Uses a removable carbon contact member.

ELECTRIC SERVICE MANUFACTURING CO.
1721 CAMBRIA STREET • PHILADELPHIA 32, PENNA.
MAKERS OF CONTACT RAIL AND WIRE SUPPORTS, AND COLLECTION DEVICES

POWER TRANSFORMERS assembled HERE..



This section of the Pennsylvania plant is known as the Finishing Department. All Power transformers stop here for final assembly and finishing before going to the Test Department.

The group of transformers pictured is representative of the types of Power transformers designed and manufactured by Pennsylvania.

Transformers in this group range from 2500 Kva to 30,000 Kva. Some are equipped with no load tap changers; others with underload tap changers.

Many types of cooling methods are represented — self-cooling, forced air cooling, and forced oil cooling.

Methods of oil preservation include Inert Gas-Oil Seal, Oil Expansion Tank, and Inert Gas Pressure Systems.

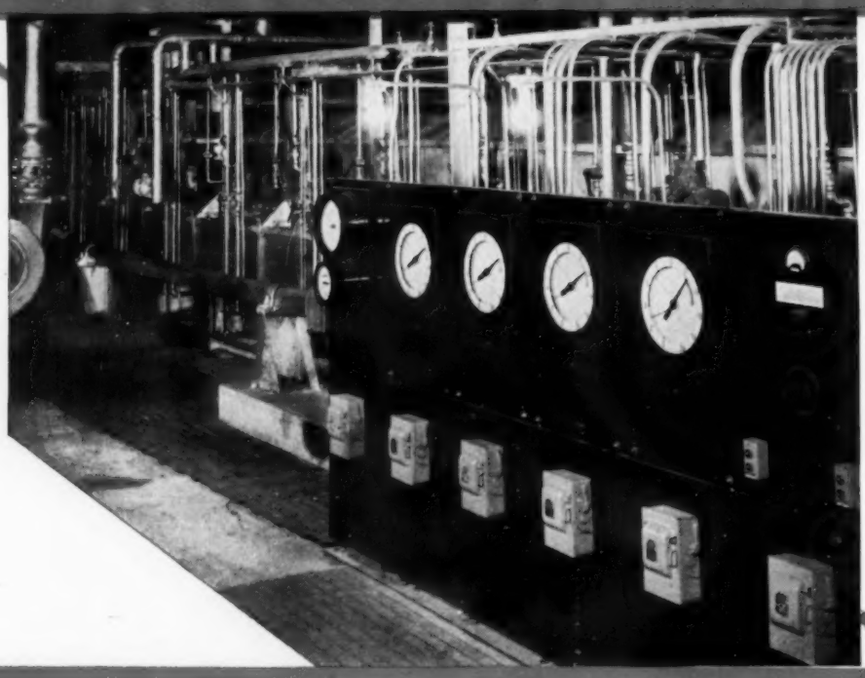
Other Power transformers regularly built by Pennsylvania have ratings up to 100,000 Kva and voltages up to and including 230 Kv.

Pennsylvania TRANSFORMERS

Pennsylvania TRANSFORMER COMPANY

CANONSBURG, PENNSYLVANIA • *Greater Pittsburgh District*

"PRACTICALLY PERFECT HEAT TREATMENT"



...WITH *ElectroniK* CONTROLLERS

AND BROWN PROPORTIONAL CONTROL RELAYS

THIS hard-to-beat combination of Brown instruments is setting new standards for quality control in the metals industry. A key operating engineer of one large producer says, "They are the nearest thing to perfection I have ever seen in automatic control" . . . referring to four-zone control on a continuous rod annealing furnace.

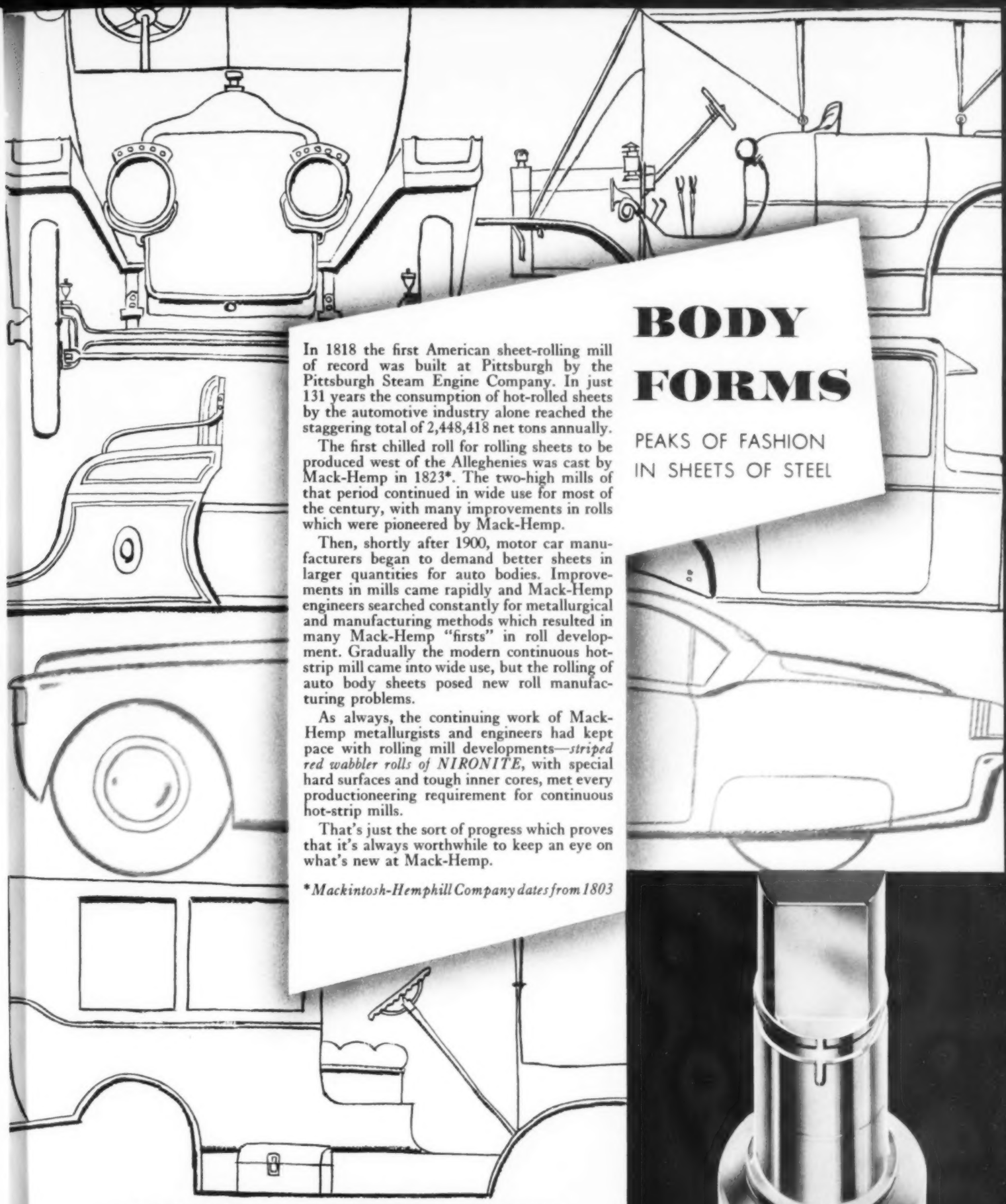
The extreme sensitivity of the famous *ElectroniK* Controller is used to its fullest advantage with the amazing versatility of the Brown Proportional Control Relay. Check these outstanding features of this new integrally mounted relay for profitable application in your plant: *Unmatched sensitivity and stability; Positive action; Full proportional band adjustment; Signal lights to indicate fuel valve operation; Manual or automatic positioning; Designed for flush mounting; Drawer-type construction for easy accessibility.*

Call in your local Honeywell engineer today . . . for a discussion of how this winning combination can add up dollar and cents savings for you. He is as near as your phone. MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4464 Wayne Ave., Philadelphia 44, Pa. Offices in more than 80 principal cities of the United States, Canada and throughout the world.

FOR METAL PRODUCING

MINNEAPOLIS **Honeywell**

BROWN INSTRUMENTS



BODY FORMS

PEAKS OF FASHION IN SHEETS OF STEEL

In 1818 the first American sheet-rolling mill of record was built at Pittsburgh by the Pittsburgh Steam Engine Company. In just 131 years the consumption of hot-rolled sheets by the automotive industry alone reached the staggering total of 2,448,418 net tons annually.

The first chilled roll for rolling sheets to be produced west of the Alleghenies was cast by Mack-Hemp in 1823*. The two-high mills of that period continued in wide use for most of the century, with many improvements in rolls which were pioneered by Mack-Hemp.

Then, shortly after 1900, motor car manufacturers began to demand better sheets in larger quantities for auto bodies. Improvements in mills came rapidly and Mack-Hemp engineers searched constantly for metallurgical and manufacturing methods which resulted in many Mack-Hemp "firsts" in roll development. Gradually the modern continuous hot-strip mill came into wide use, but the rolling of auto body sheets posed new roll manufacturing problems.

As always, the continuing work of Mack-Hemp metallurgists and engineers had kept pace with rolling mill developments—*striped red wabbler rolls of NIRONITE*, with special hard surfaces and tough inner cores, met every productioneering requirement for continuous hot-strip mills.

That's just the sort of progress which proves that it's always worthwhile to keep an eye on what's new at Mack-Hemp.

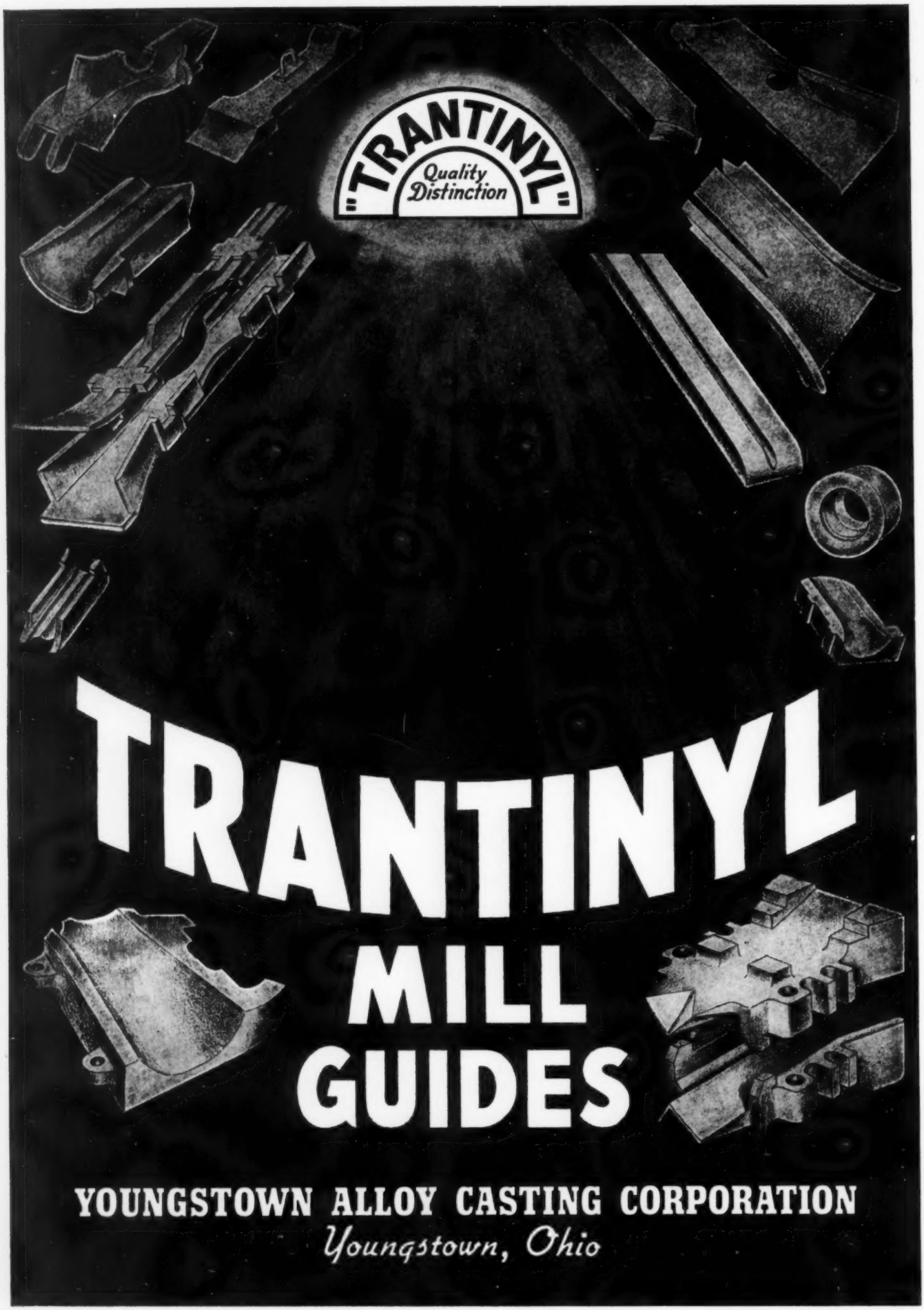
**Mackintosh-Hemphill Company dates from 1803*

MACKINTOSH-HEMPHILL COMPANY

Makers of the Rolls with the Striped Red Wabblers

PITTSBURGH AND MIDLAND, PA.

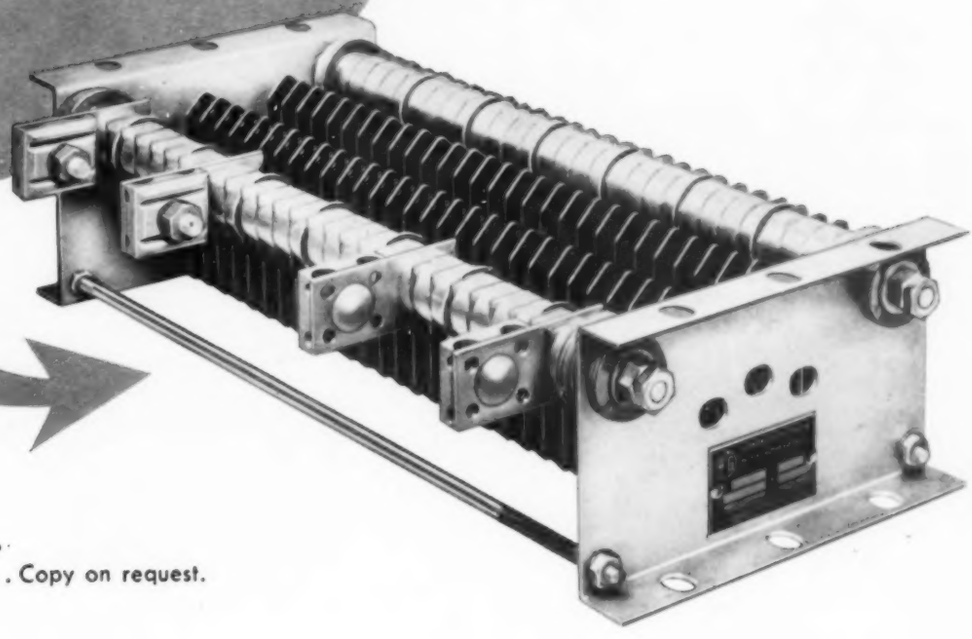
MACKINTOSH-HEMPHILL PRODUCTS INCLUDE: rolls . . . steel and special alloy castings . . . completely integrated strip mills . . . heavy duty engine lathes . . . the new Mackintosh-Abramsen straighteners . . . improved Johnston patented corrugated cinder pots and slag-handling equipment . . . shape straighteners . . . end-thrust bearings . . . shears . . . levellers


TRANTINYL
Quality
Distinction
TRANTINYL
MILL
GUIDES
YOUNGSTOWN ALLOY CASTING CORPORATION
Youngstown, Ohio

P-G *Resistance Values*

REMAIN UNUSUALLY CONSTANT . . .

regardless of temperature or age!



BULLETIN No. 500 . . .
Gives detailed information . . . Copy on request.

Ohmic values of P-G Steel Resistance Grids show a minimum of change when subjected to temperatures usually encountered under extremely severe service. Thus remarkably accurate and constant control is assured. All steel construction, mica insulation, with provision for expansion and ample ventilation give that extra stamina needed for trouble-free heavy duty resistor service. For any job . . . where your operating conditions are severe . . . specify P-G.

P-G

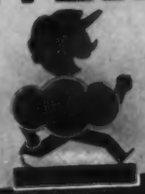
The Nonbreakable Steel Grid Resistor

THE POST-GLOVER ELECTRIC COMPANY

• ESTABLISHED 1892 •

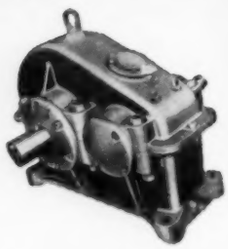
221 WEST THIRD STREET, CINCINNATI 2, OHIO

There's a De Laval Reducer for EVERY SERVICE



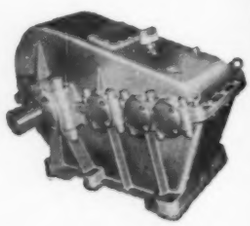
IMO-De Laval Herringbone Gear Reducers

IMO-De Laval Herringbone Gear Speed Reducers are made in single, double and triple reduction units for ratios up to 300 to 1 and for transmitting up to 1000 hp.



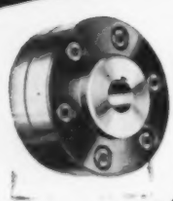
Single reduction

Double reduction

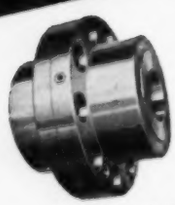


Triple reduction

IMO-De Laval Gear and Crown Couplings



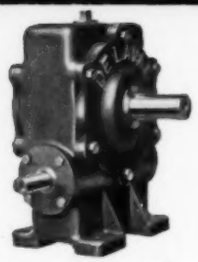
IMO-De Laval Crown coupling.



IMO-De Laval Gear coupling.

IMO-De Laval Worm Gear Reducers

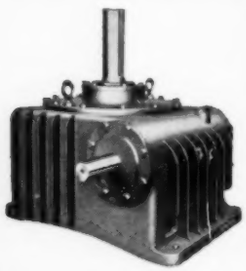
IMO-De Laval Worm Gear Speed Reducers are made in single and double reduction units with ratios up to 8000 to 1 and for transmitting up to 250 hp.



Horizontal, single reduction bottom or top drive in 3" and 3½" center distances.

Horizontal, single reduction bottom or top drive for torque service and moderate overhung loads.

Horizontal, single reduction bottom or top drive, torque or heavy overhung load service.



Vertical shaft, single reduction.

Double reduction worm gear with horizontal shaft.

Double reduction worm and helical with horizontal shaft.

Double reduction worm and helical with vertical shaft.

DE LAVAL

IMO-DE LAVAL PRODUCTS DIVISION

Send for Catalog GWB-26-R.

DE LAVAL STEAM TURBINE CO.

TRENTON 2, N. J.

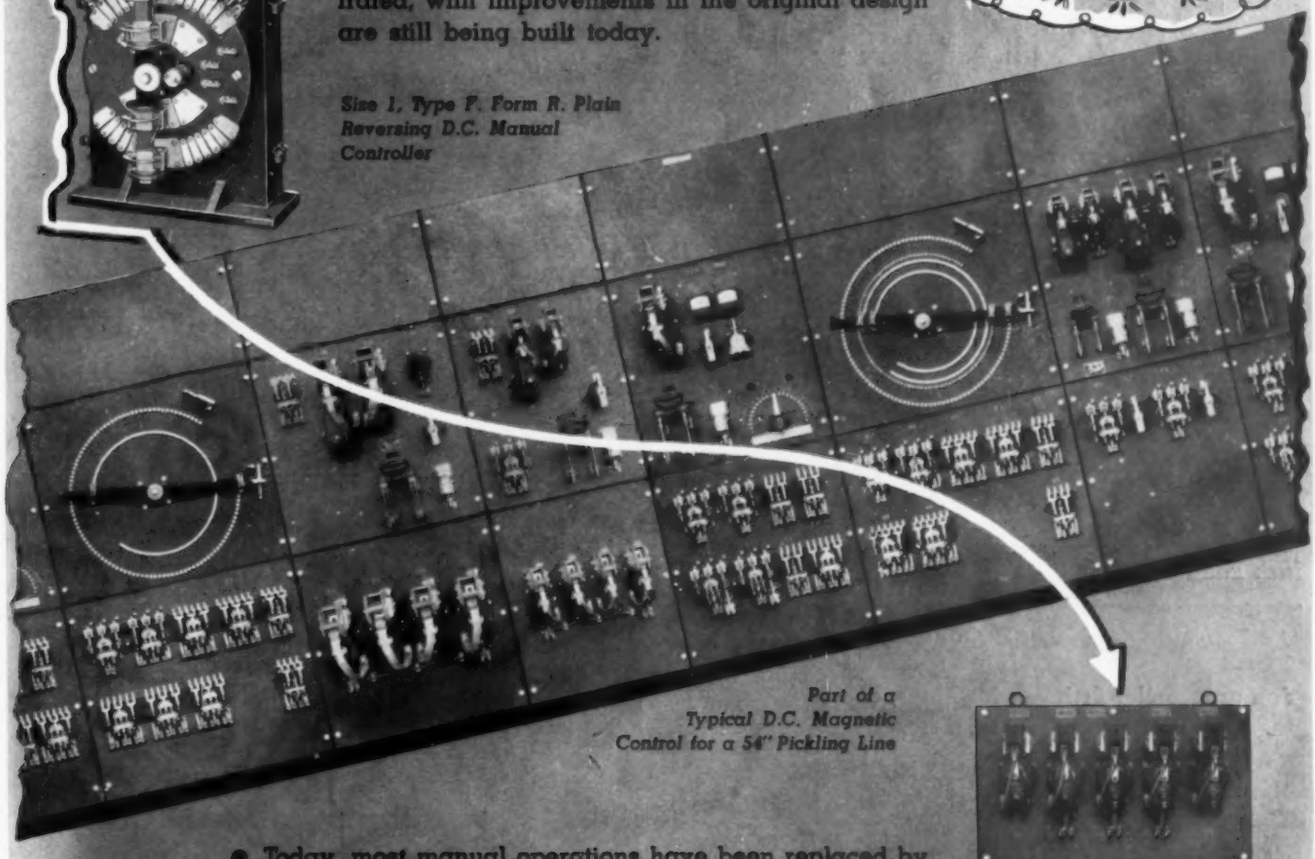
WG-26

Celebrating our 25th ANNIVERSARY

The Clark Controller Company was incorporated July 15, 1925, exactly 25 years ago . . . Our first Controller—a D.C. Manual Reversing Face Plate Controller—was delivered soon after.

Manual Face Plate Controllers, such as illustrated, with improvements in the original design are still being built today.

Size 1, Type F, Form R, Plain Reversing D.C. Manual Controller



Part of a Typical D.C. Magnetic Control for a 54" Pickling Line

● Today, most manual operations have been replaced by automatic controls, such as the Full Magnetic D.C. Controller for Crane Bridge or Trolley Panel shown at the right.

Typical of the more complicated apparatus now being built by CLARK is the D.C. Magnetic Control for a 54" Pickling Line, a section of which is shown above.

Twenty-five years of practical engineering experience in designing and building electrical control for steel, non-ferrous and other heavy-duty industrial applications is available to solve your electrical control problems.

D.C. Controller for Crane Bridge or Trolley

THE CLARK CONTROLLER CO.

ENGINEERED ELECTRICAL CONTROL · 1146 EAST 152ND STREET, CLEVELAND 10, OHIO

Cut Installation Costs

WITH 30% SMALLER

ROCKBESTOS

A.V.C.®

USE A SMALLER CABLE!

With a 230 ampere load you use Size 000 A.V.C. instead of 300 MCM RH*.

SAVE ON CONDUIT!

You use 2-inch conduit rather than 2½-inch conduit.

SAVE ON FITTINGS!

You use smaller fittings—bushings, couplings, terminators, connectors, etc.

SAVE ON LABOR!

Because the cable is lighter, smaller, you can pull it through the conduit easier, faster, and, of course, *cheaper.*

The more efficient current carrying capacity of Rockbestos A.V.C. means plenty of savings for you. Write for the booklet "Cut Current Carrying Costs."

*Comparison with Type RH, 3 conductors in conduit, 40°C — (104°F). See Chapter X, National Electrical Code.

ROCKBESTOS PRODUCTS CORPORATION

New Haven 4, Conn. • New York • Cleveland • Chicago • Detroit
Pittsburgh • St. Louis • New Orleans • Los Angeles • Oakland, Calif.

Hi ... *Your best buy*

*Rockbestos A.V.C. has a Higher Ampere Rating

For Rock Bottom Costs From Start to Finish!

START . . . FLUXING STONE
A P&H Model 1400 Diesel-Electric (4 yd.) shovel, owned by Drummond Dolomite Inc. at Drummond Island, Michigan.

FINISH . . . BLAST FURNACE SLAG
A P&H Model 1400 Diesel-Electric shovel owned by the Buffalo Slag Co., Buffalo, New York.

P&H DIESEL-ELECTRIC SHOVELS

with MAGNETORQUE* HOIST DRIVE

Now, you can have electric shovel efficiency *anywhere* with a P&H Diesel-Electric quarry and mining shovel. It's a complete electric shovel . . . with the addition of a diesel engine to furnish power . . . entirely independent of high line service.

Years of the toughest rock digging have proved the P&H Diesel-Electric from every standpoint . . . dependable operation . . . less maintenance . . . rock bottom tonnage costs.

This simplified P&H Diesel-Electric shovel is made possible by the exclusive P&H Magnetorque Hoist Drive. Hoist generator, hoist motor, slip friction clutch and other mechanical devices are completely eliminated. Magnetorque is only one of many P&H Added Values. Ask for Bulletin X83-DE.

Every Third P&H Electric Shovel Sold is a Repeat Order.

*Trade-Mark of Harnischfeger Corporation for electro-magnetic type clutch

P&H **ELECTRIC SHOVELS**
4455 West National Avenue
Milwaukee 14, Wis.

HARNISCHFEGER CORPORATION

LEADING THE FIELD IN ELECTRIC SHOVEL DEVELOPMENTS • EXCAVATORS • OVERHEAD CRANES • HOISTS • ARC WELDERS AND ELECTRODES • SOIL STABILIZERS • CRAWLER AND TRUCK CRANES • DIESEL ENGINES • CANE LOADERS • PREASSEMBLED HOMES

...always uniform
...like INTERNATIONAL GRAPHITE ELECTRODES

International GRAPHITE AND ELECTRODE CORP.
ST. MARYS, PA.

Roll users point with pride to this Roll mark

MOLYBDENUM CHILLED IRON ROLLS

ATLAS and ATLAS "B" ROLLS
(Alloy Grain Type)

CLIMAX and AJAX ROLLS
(High Alloy Grain Type)

"X" and "XA" ROLLS
(Alloy Grain Type)

SPECIAL TUBE MILL ROLL

PLAIN CHILLED IRON ROLLS

SUPERIOR "X" ROLLS
(Nickel Grain Type)

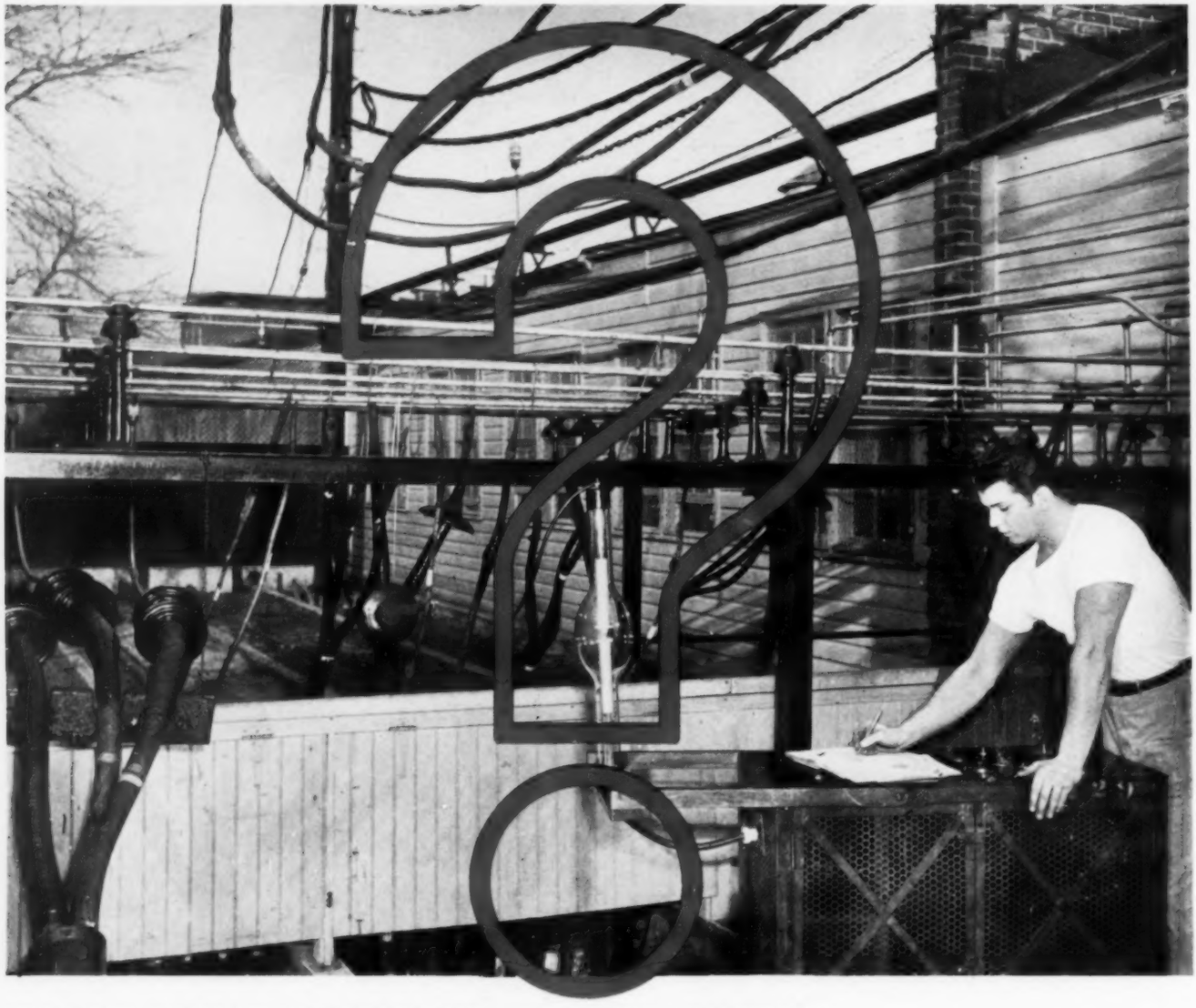
AJAX DUPLEX ROLLS
(High Alloy Grain Type)

SPECIAL PROCESS ROLLS
(Chill and Grain Type)

OVER 90 YEARS LEWIS OF ROLL MAKING

LEWIS FOUNDRY AND MACHINE DIVISION OF BLAW-KNOX COMPANY · PITTSBURGH, PA.

MANUFACTURERS OF ROLLS AND ROLLING MILL MACHINERY FOR THE IRON, STEEL AND NON-FERROUS INDUSTRIES



WHERE CABLE QUESTIONS OF THE FUTURE ARE BEING ANSWERED NOW

THIS is the Okonite proving ground. Within its bounds are concentrated the toughest cable tests that experience can devise. Here, lengths of every kind of cable—overhead or underground, clad in every type of insulation and protective covering—go in to stay for years, under continuous high voltage and alternating load cycles.

Underground cables are buried in "graves" filled with soils of all types, saturated with chemical wastes, sewage, salt brine... attacked by every enemy that may be encountered in actual installations. Overhead cables are exposed to a wide range of year-round weather conditions. Periodic examination of the cables includes disinterment, careful examination of coverings, complete electrical and physical measurements to determine rates of deterioration. Only the fittest can eventually survive.

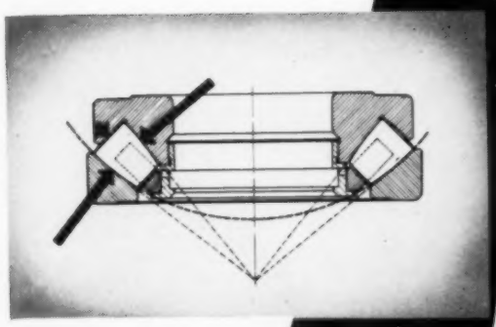
But this rigorous proving ground is open only to the "elect"—cable specimens that have previously survived months and years of hundreds of searching laboratory tests and experiments. Nor are all these results considered conclusive. No matter how successful in the laboratory and on the proving ground, every new Okonite wire or cable must pass the test of experience in the field before the final verdict is returned.

Now in its thirteenth year of operation, the Okonite proving ground is but one phase of the sternest testing techniques employed in the cable manufacturing industry today. It helps to explain why, tomorrow as in the past 72 years, you can continue to depend on Okonite for the right answers to your toughest cable problems. The Okonite Company, Passaic, N. J.

THE BEST CABLE IS YOUR BEST POLICY

OKONITE OKONITE SINCE 1878 *insulated wires and cables*

8341



ONLY SKF

ENGINEERS A SPHERICAL ROLLER THRUST BEARING WITH

1. Capacity exceeding 2,000,000 lbs.
2. Rolling alignment
3. Continuous operation at sustained high speeds

Here's the *one* spherical roller thrust bearing with undiminished capacity at sustained high speeds, even if there's misalignment between the shaft and housing bore.

SKF engineering makes it possible. Look at the drawing. Load components firmly contact the roller ends against the high guide flange, to assure positive guiding of the rollers without excessive pressure on their ends. Misalignment doesn't matter —the outer bearing race is a section of a sphere on which the inner race and roller assembly align freely.

What this amounts to is one more example of the advanced, pioneering kind of engineering that puts the right bearing in the right place—the SKF kind of leadership that has always *anticipated* the needs of American Industry. **SKF** INDUSTRIES, INC., PHILADELPHIA 32, PA., *Pioneers of the Deep Groove Ball Bearing, Spherical Roller Bearing, Self-Aligning Ball Bearing.* 7097

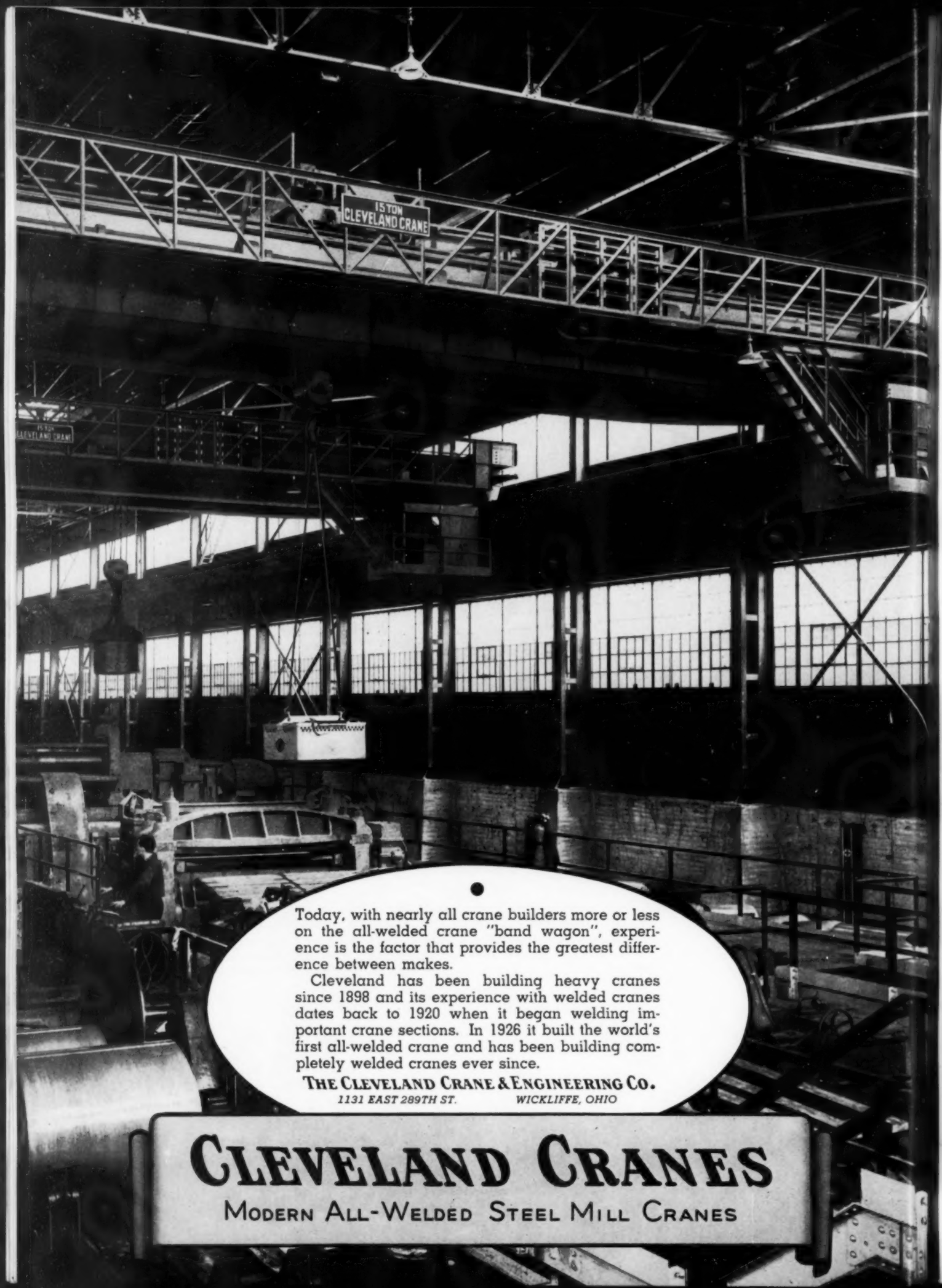
SKF

BALL AND ROLLER BEARINGS

8 REASONS WHY SKF IS PREFERRED BY ALL INDUSTRY

Integrity — Craftsmanship — Metallurgy — Tolerance Control

Surface Finish — Product Uniformity — Engineering Service — Field Service



Today, with nearly all crane builders more or less on the all-welded crane "band wagon", experience is the factor that provides the greatest difference between makes.

Cleveland has been building heavy cranes since 1898 and its experience with welded cranes dates back to 1920 when it began welding important crane sections. In 1926 it built the world's first all-welded crane and has been building completely welded cranes ever since.

THE CLEVELAND CRANE & ENGINEERING CO.
1131 EAST 289TH ST. WICKLIFFE, OHIO

CLEVELAND CRANES

MODERN ALL-WELDED STEEL MILL CRANES

Crops *and* Shorts

WHEN President Truman vetoed the freight absorption bill recently passed by Congress, he stated that freight absorption was permissible at present, *if* – – –. And thus another was added to the growing list of "if" laws that govern business. Too many of our laws do not conclusively prohibit or conclusively permit various actions, but depend on future rulings of bureaus or courts. It is usually impossible to get an advance ruling on a proposed action. Hence, business, if it decides to take action, must chance the possibility of being precondemned as a criminal and hailed into court, with all the attendant publicity and expense. What we need are fewer "if" laws.

▲

ACTUALLY, the freight absorption question is not particularly important to steel producers with present peak business. The retention of "f.o.b.-mill" prices, however, may tend to accelerate the movement of consumers into steel producing areas and the construction of new producing facilities in large consumer areas. Likewise, it may lead to increased importation of steel by consumers not favorably located with respect to domestic producers. Nails, wire, sheet bar and concrete bar are already available from Europe at prices materially lower than domestic prices.

▲

AFTER emerging from a session with a census taker, one of our correspondents thinks that if government continues to pry into private affairs, the census report will make as interesting reading as the Kinsey report.

▲

WE are sure that the following came from some engineer's pen:

Naught's a naught,
And a figger's a figger —
I wish I had made my estimate bigger.
I hate to state,
I'm sad to relate,
The cost is more than my estimate.

▲

SPEAKING at the dinner of the AIME Open Hearth Committee in Cincinnati, W. W. Sebald, president of Armco Steel Corp., suggested the formation of an organization, "Economics Anonymous," to follow the methods of Alcoholics Anonymous in an effort to help people think straight on economics.

We believe this particular problem poses perhaps the greatest danger facing the future of this country. People must learn that you don't really get anything for nothing. If the government seems to be giving you something, believe us, you're paying for it. If fair wages, permanent employment and security are what is wanted, then thought must also be given to profits for employers. If there is no incentive to invest in business, our economy will stagnate. It is the employees' job to help make the profits that insure security, and anything they do to interfere with profits is an attack upon their own welfare.

That certainly sounds simple and logical. Now, what do we do about it?

▲

THE house organ Curtis Courier carried some sage advice recently. It said: "Business men who go to the club every noon and lunch at some big table with men of their own class are subjecting themselves to intellectual inbreeding. By no possibility can they get a new point of view there. They get the same old ideas. A business man might find his mind stretching a bit if he lunched occasionally with a poet or a preacher or the bootblack or a bartender."

We have often felt it would be beneficial if labor leaders were invited to speak before meetings of business men, and business leaders before labor unions. As it is now, business men speak to business men, labor leaders to unions, Republicans to Republicans, Democrats to Democrats, and here we are preaching to you. The applause is deafening, but there are no new converts.

▲

AN observation in the Houghton Line: "Vacations are easy to plan. The boss tells you when and the wife tells you where."

▲

ADDRESSING the National Association of Purchasing Agents, Ben Moreell, president of Jones & Laughlin Steel Corp., said: "I do not fear the Russian Army, or the atom bomb, or the hydrogen bomb, nearly so much as I fear this concept of using the law to relieve individuals of the responsibility for their own welfare and to deprive them of their liberties. We can all see the danger of a military threat to our freedom. If we are attacked we will fight, and we will win. But few of us appear to understand this insidious process whereby we use our own laws and our own government to destroy our own liberties just as surely as if some foreign conqueror had power over us."

▲

THIRTY years ago, Thomas A. Edison said: "It used to be fashionable to be ambitious. If my life had been made up of eight-hour days, I do not believe I would have accomplished very much. This country would not amount to as much as it does if the young men of 50 years ago had been afraid they might earn more than they were paid."

▲

ALTHOUGH the general reaction to General Motors' settlement with UAW seemed to be favorable, there is a definite feeling in many quarters that the settlement furthered inflation and provided the springboard for further wage increases in all industry. The wisdom of binding the company to increase wages every year for the next five years is questioned by many, and there seems to be considerable sentiment that the company should have put forth greater efforts to hold the line. On the other hand, five years of industrial peace (if they get it) must look like the "pot of gold" to any company. Only the future can show what was best for the company, for the workers and for the country.

ORE BENEFICIATION

Through A-C Equipment and Engineering

FOREIGN ORE DISCOVERIES ARE GOOD NEWS, but domestic mines still will supply the bulk of the ore consumed in the U. S. Problems of transportation and availability will assure this. *One thing certain* in this changing picture, more mining, processing and handling will be required on domestic ores as quality lowers.

In iron mines throughout U. S., Allis-Chalmers equipment for half a century has been processing ores for the steel industry. Its research, engineering and experience is today helping ore producers meet the challenge of economical beneficiation of leaner ores and taconites.

Operation photos, below and right, show A-C ore beneficiation equipment now in wide use. Allis-Chalmers offers you this kind of *undivided responsibility* for process, drive and control equipment all along your flow sheet.

A-C also operates a complete commercial research laboratory and pilot plant to aid you in developing new processes. For detailed information on equipment and services, call your nearest A-C office. A-3095

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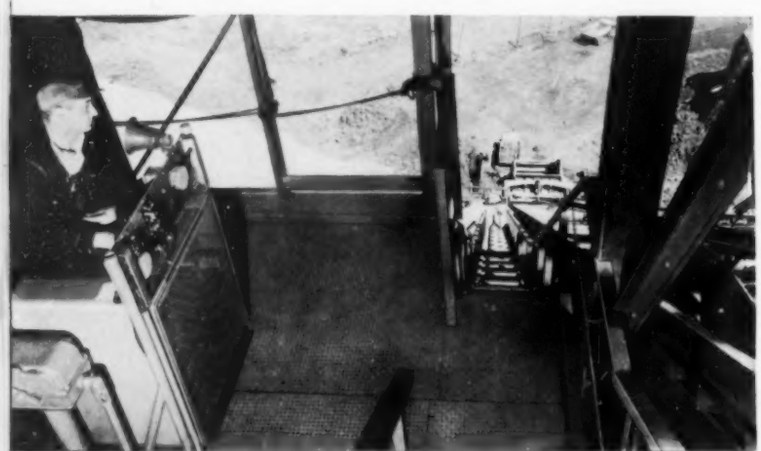
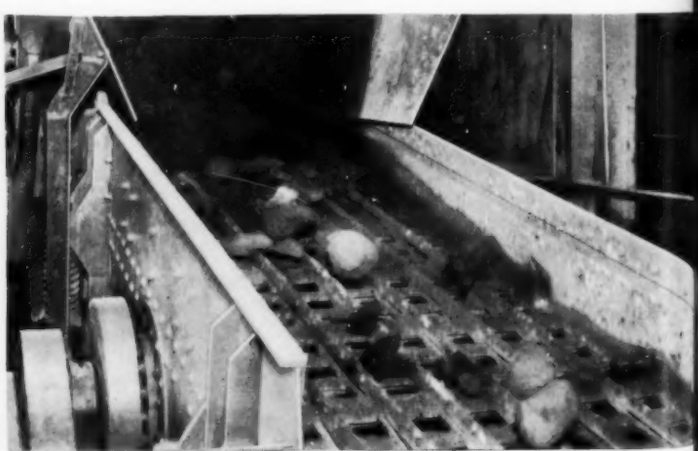


1 **SINCE UP TO THREE TONS** of ore are needed to produce one ton of concentrate, large quantities of low grade ore must be removed from the deepening mines. Mesabi range mine skip hoist above is A-C, built by the *only* manufacturer of hoists and *all* auxiliaries.



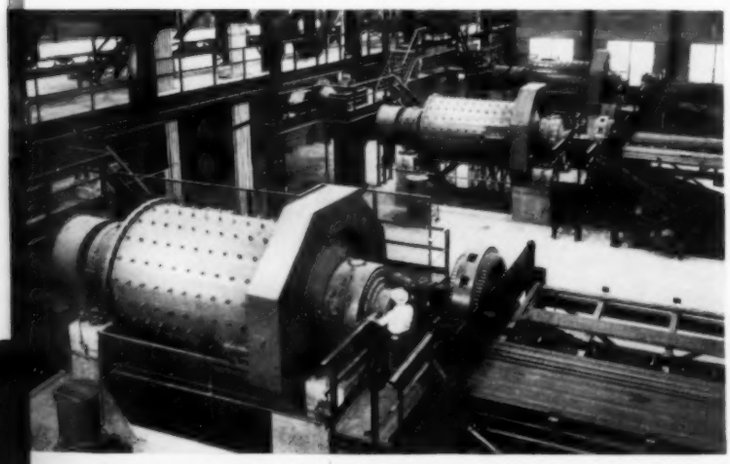
2 **FINES ARE OFTEN SCALPED** from run-of-mine ore on sturdy 1000 tph Style C vibrating screens like this one at a Minnesota iron mine. Allis-Chalmers builds *six* separate types of vibrating screens to meet varying beneficiation requirements.

3 **TOUGH, ABRASIVE, LOW GRADE** iron ores are crushed in high output primary gyratory and jaw crushers. This 60-in. Superior• McCully crusher is in use in the Lake Superior region. Write for Bulletin 07B6004 for complete details on this type of crusher.

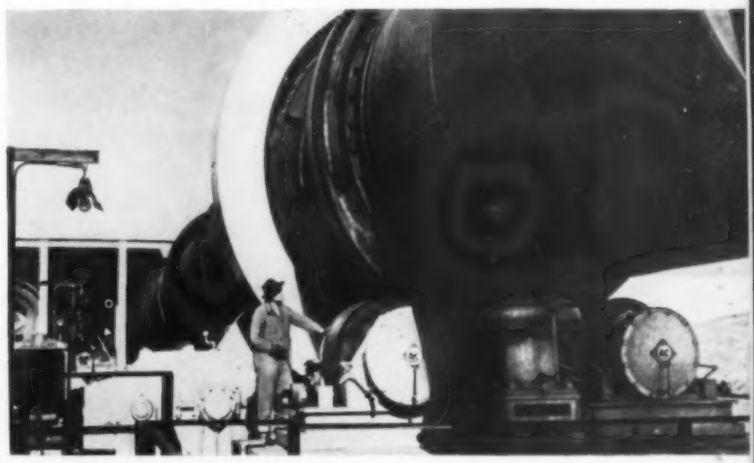
4 **FINE REDUCTION** of the iron ore is often accomplished with *Hydrocone* gyratory crushers. Two are seen working in parallel at this Adirondacks iron mine and beneficiation plant. Write for Bulletin 07B7145 for complete description and operating data.

5 **THESE LOG WASHERS** are used to remove silica and medium sticky clay from crushed iron ore. Contra-rotating steel paddles produce a scuffing, scouring and sluicing action. Allis-Chalmers makes all basic types of washing equipment. See Bulletin 07B6411.

6 **IN CONCENTRATING IRON ORE** by the heavy density process, *Low-Head* vibrating screens are widely used for recovering media. The first screen section drains the media while the second section washes at this Minnesota plant. Write for Bulletin 07B6330.



7 **IRON ORE IS FINELY GROUND** in three A-C 8 ft x 12 ft rod mills ahead of magnetic separation at this Adirondack plant. A-C builds *five* separate types of grinding mills to meet varying plant requirements. Request Bulletin 07B6718 for full details.



8 **NODULIZING OF BENEFICIATED IRON ORE** so that it can be used efficiently as blast furnace feed is the job of this Allis-Chalmers 11 ft, 6 in. x 300 ft rotary kiln at a southern iron mine and beneficiation plant. Bulletin 07B6368 contains full description.

EQUIPMENT FOR IRON ORE BENEFICIATION: Hoists . . . Jaw and gyratory crushers . . . Vibrating screens . . . All types of washers . . . Concentrating jigs . . . Grinding mills . . . Rotary kilns and coolers . . . Centrifugal pumps . . . *Texrope* V-Belt drives and sheaves . . . All types and sizes of Electric motors . . . Starters . . . Complete power generation, distribution, control equipment. Write for literature.

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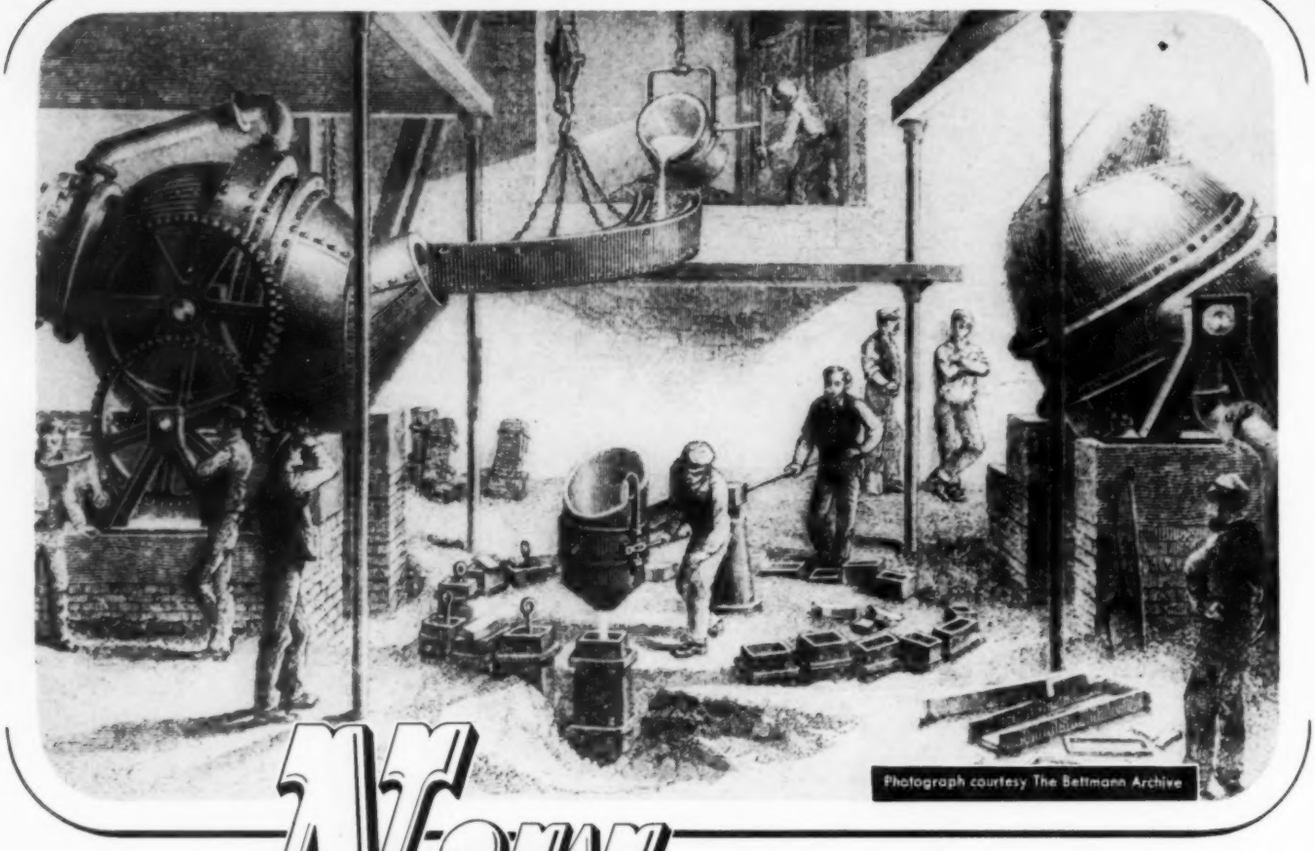

Photograph courtesy The Bettmann Archive

THIS WAS *New* IN THE STEEL INDUSTRY *in '72*

Stop—and compare the "Manufacture of Bessemer Steel" shown in the old engraving above with modern steel production, and you'll realize the vast changes and improvements that have been made through the years in every phase of the industry. You'll also realize that you and every man in a supervisory capacity in your plant must attend the big Exposition in Cleveland this year and be "brought up-to-date" on the latest developments in equipment, methods, supplies and services.

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Iron and Steel ENGINEER

JULY, 1950 VOLUME XXVII NUMBER VII

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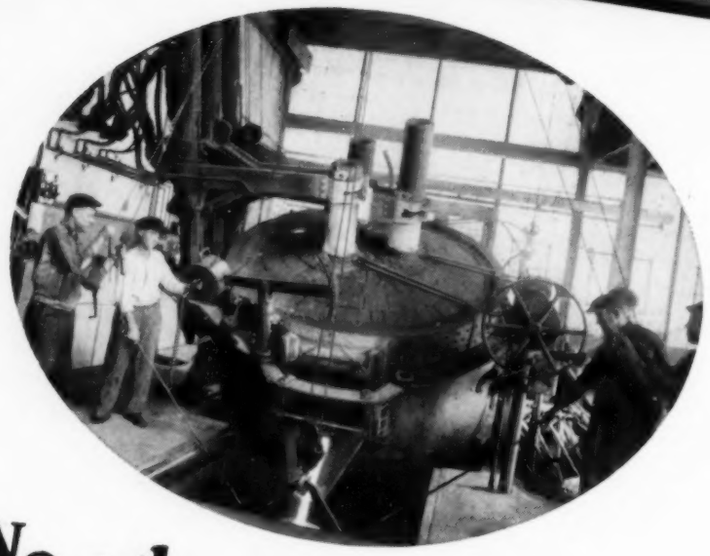
31

years ago:

McQuay-Norris

said...



No other Piston Ring has Metal like this

To improve on cupola-melted piston ring metal, the McQuay-Norris Manufacturing Company has changed all old established iron foundry practice. They have applied to piston ring manufacture the same method that has revolutionized the making of high-grade alloy steels—the Electric Furnace—the only one used in this country today for melting commercial gray iron. This improvement places McQuay-Norris Rings in still another class by themselves.

Written 31 years ago, that story is just as factual today: The accurate control possible with an electric furnace, the closer grain structure obtained at the higher temperatures, the greater uniformity possible; all result in better castings.

McQuay-Norris now has two Lectromelt Furnaces. That 3-ton furnace bought in 1919 has been modernized with Lectromelt electronic controls and other refinements. The second, installed in 1943, will do almost as much work as the old-timer although it's rated at half the capacity. It is top charged, rather than door charged.

If you're interested in learning what a Moore Rapid Lectromelt Furnace will do for you, write Pittsburgh Lectromelt Furnace Corporation, 310 32nd Street, Pittsburgh 30, Pennsylvania.

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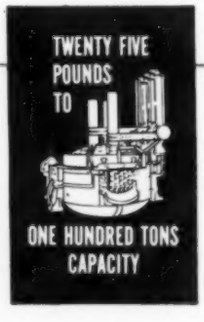


REPORT OF AISE WIRING COMMITTEE

By C. G. DIMITT
Co-Chairman
AISE Crane Wiring Committee

. . . . the following report outlines the research work and technical studies on which AISE Standard No. 8, (Tentative) Crane Wiring Standards is based . . . . this specification was published in the June 1950 Iron and Steel Engineer . . . .

▲ IN April 1948, the Association of Iron and Steel Engineers' Crane Wiring Committee with Mr. J. E. Bodoh as chairman began the study of crane wiring. Experiences with cranes wired by crane builders indicated considerable differences in the methods used by equipment suppliers and users in selecting conductor cables for mill type motors on overhead traveling cranes. Therefore, the standardization of conductor cable sizes was selected as the first objective of the committee.

CLASSIFICATION OF CRANE SERVICE

The study of conductor cables for crane service was initiated by a study of the conditions under which cranes will operate. A review of Mr. I. E. Madsen's "Steel Plant Service Requirements for Cranes" indicated that these data could be used as a basis for a ready reference chart. Mr. Madsen's article published in the 1948 Proceedings, AISE, p 674 and included in the new AISE Crane Specifications as Table 43-III is reproduced in part in Table I. The ready reference chart is shown in Table II. It will be noted that the tabulation of types of cranes follows Table I very closely.

Two general types of service have been adopted, average duty and heavy duty. These selections are based on the experience and judgment of the committee, on the "average number of hours operation in one year," the "per cent time on in operation hours," and the "number of moves per hour." Referring to Table I. a crane operated over 4300 hours a year (50 per cent of the overall average hours), having a motion with 40 per cent or more time on in operational hours, or having more than 35 moves per hour, may generally be classified as subject to heavy duty service. A crane operated less than 4300 hours a year, having all motions requiring less than 40 per cent time on in operational hour and having less than 35 moves per hour may be generally considered as subject to average duty service. If the maximum crane temperature during operation is over 55C (131F) the service may be classified as high temperature. If the maximum crane temperature is under 55C (131F), the service may be classified as average temperature. Classifications of indoor, outdoor, and corrosion resistant have been included to cover distinctions in equipment or protective features which may be necessary for cranes in such service. Due to the differences in plant layout, given types of cranes may be indoor and outdoor, average and high temperature, or average and heavy duty. A service classification may be fully covered by a symbol such as IB2, for open hearth charging machines, meaning that the classification is indoor, heavy duty, and subject to high temperature. These symbols are used for classification reference in the proposed conductor cable standards.

CONDUCTOR CABLE RATINGS

General—The proper application of conductor cables to overhead travelling cranes has been the subject of much discussion and study for a considerable period of time. Strict compliance with the National Electrical Code, Chicago Electrical Code, or similar authority does not afford a simple solution to the problem of selecting conductor cable and conduit systems which will economically satisfy requirements in the limited spaces and critical clearances available. This is particularly true of heavy duty mill cranes and similar material handling equipment such as ore and coal bridges, which employ the larger size motors.

In general, the selection of suitable size conductor cables for mill type motor circuits for steel mill crane drives is affected to a great extent by the judgment

TABLE I

Crane Service Data

	Crane			Bridge			Trolley			Main hoist			Auxiliary hoist		
	Average number of hours operation in one year	Normal ambient temperature during operation	High ambient temperature during operation	Average number of hours operation in one year	Per cent time on in operational hour	Number of moves per hour	Average number of hours operation in one year	Per cent time on in operational hour	Number of moves per hour	Average number of hours operation in one year	Per cent time on in operational hour	Number of lifts per hour	Average number of hours operation in one year	Per cent time on in operational hour	Number of lifts per hour
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Coke Plant and Blast Furnace Cranes:															
Drawing machine (coke pusher)	7200	80	135	3240	45	17	2088	29	9	1296	18	7	1440	20	6
Bucket handling	3240		110	1458	45	19	1458	45	25	2009	62	25	2106	65	27
Stock yard	6840			3078	47	14	3762	55	48	2941	43	38	2736	40	100
Slag handling	5400		100	1670	31	21	1836	34	30	2052	38	21	3240	60	35
Scrap yard	7200			3240	45	30	1440	20	27	4104	57	80			
Cast house	1080			648	60	32	400	37	32	616	57	75	432	40	20
Pig machine						15		90	15		90	4		5	2
Ladle house	1800			360	20	22	630	35	25	576	32	15	846	47	17
Skull cracker	720			36	5		576	80	30	648	90	30	14	2	1
Sand house (bucket)	360			324	90	21	342	95	21	54	15	21	324	90	20
Setting basin	720			360	50	30	108	15	60	180	25	60	216	30	60
Car repair shop	1440			216	15	20	288	20	35	432	30	40	288	20	20
Ore bridge	7560			756	10	10	3780	50	35	454	6	35	3024	40	35
Coke ovens (Coal bridge)	5760			1440	25	15	2880	50	78	634	11	78	2419	42	78
2. Open Hearth, Electric Furnace, Bessemer Cranes:															
Charging machines	6840	91	111	2120	31	98	3146	46	89	1847	27	80	1368	20	88
Hot metal crane (charging)	6480	118	129	2850	44	27	1426	22	32	1750	27	13	2592	40	31
Ladle	6480	101	108	2916	45	33	3110	48	23	1690	26	9	1361	21	18
Metal mixer crane	3600	90	120	648	18	12	1008	28	18	1980	55	20	1080	30	33
Electric furnace charging cranes	2880			864	30	45	864	30	60	1728	60	100			
Stock yard	6480	70	80	1940	30	76	2851	44	89	3110	48	93			
Scrap preparation					10	64		50	64		40	32			
Scrap baler crane	7560			2040	27	40	2268	30	40	3780	50	80			
Scrap shear crane	7560			4990	66	40	1275	17	40	4838	64	80			
Hot top	5400		130	1350	25	55	810	15	57	1890	35	30	2430	45	90
Bucket	5040			2420	48	52	2218	44	49	2066	41	43	1915	38	20
Slag handling	6480			1820	28	25	1944	30	8	2268	35	10			
Cinder yard	5040	70	100	2120	42	55	2621	52	80	3276	65	82	4032	80	25
Skull cracker	6480	70	80	1620	25	70	2592	40	71	3110	48	23	3564	55	37
General service	3960		100	1310	33	22	911	23	26	555	14	23	1584	40	56
3. Ingot Handling Cranes:															
Ingot handling	6840			1500	22	30	1163	17	33	3762	55	17	342	5	28
Soaking pit	3960	122	145	1660	42	42	1703	43	42	2020	51	60	832	21	50
Stripper	4680	70	113	1070	23	38	1638	35	38	2059	44	64	1123	24	31
Mold yard	6120	72	101	2570	42	44	1714	28	63	2815	46	55	612	10	20
4. Rolling Mill Cranes:															
Slab yard	6480	60	100	3629	56	26	1944	30	34	2786	43	30	778	12	16
Slab furnace charging	4680		105	1400	30	40	1640	35	45	2800	60	61	468	10	10
Plate and strip handling	6480	110	112	3694	57	27	1426	22	26	2203	34	41			
Billet mill	4320		108	1690	39	23	1166	27	23	2030	47	31			
Billet shipping	7200	100	100	935	13	10	864	12	10	1800	25	35			
Rail mill	3600		100	1440	40	10	720	20	20	1800	50	30			
Rail loading dock	3240	100		2430	75	20	1620	50	20	1620	50	20			
Rail shipping	7920			3240	41	30	4356	55	30	3722	47	80			
Hot mill	5400		115	1400	26	18	1296	24	22	1188	22	13	1782	33	15
Cold strip mill	6840	75	100	2530	37	20	1984	29	27	1505	22	26	2120	31	24
Coil storage	7920	75	120	5227	66	73	3247	41	72	3485	44	66			
Roll shop	4320	75	90	1730	40	28	1166	27	24	1037	24	19	1080	25	26
Mill service	5040	90	110	1810	36	30	1260	25	30	1663	33	19	1865	37	40
Machine shop	5040			1810	36	31	1410	28	41	1560	31	33	2020	40	30
Cooling building	5760		132	1840	32	26	2189	38	27	2822	49	35			
Inspection and conditioning	3600			1800	50	50	1080	30	45	2520	70	75	180	5	10
Pit cover	5400		100	2700	50	25				1350	25	20	1350	25	25

TABLE I — Continued

Crane Service Data

	Crane			Bridge			Trolley			Main hoist			Auxiliary hoist		
	Average number of hours operation in one year	Normal ambient temperature during operation	High ambient temperature during operation	Average number of hours operation in one year	Per cent time on in operational hour	Number of moves per hour	Average number of hours operation in one year	Per cent time on in operational hour	Number of moves per hour	Average number of hours operation in one year	Per cent time on in operational hour	Number of lifts per hour	Average number of hours operation in one year	Per cent time on in operational hour	Number of lifts per hour
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
5. Finishing Mill Cranes:															
Slab storage	6480	80	100	1944	30	40	1944	30	40	1944	30	20	324	5	2
Billet yard	3960			1660	42	32	475	12	32	1069	27	45			
Furnace room	4320			2592	60	30	648	15	30	1080	25	30			
Mill service	5040	80	105	1870	37	19	1411	28	23	1562	31	17	1109	22	25
Shipping	5760	70	100	2995	52	35	1382	24	36	2304	40	52			
Warehouse	5040	75	100	2320	46	31	1260	25	32	2419	48	35			
Sorting room	7200			3600	50	60	1800	25	60	2160	30	60			
Scale pit	360			126	35	25	72	20	25	324	90	25	324	90	25
Hot bed	1440			216	15	5	144	10	17	288	20	15			
Pickling	6840	80	110	2800	41	30	1710	25	39	2462	36	47			
Quenching			100		5	2		5	2		5	2			
Tin mill	6840	75	100	2530	37	36	1710	25	41	2394	35	42	684	10	20
Annealing	7200	67	116	2890	40	22	2232	31	24	2016	28	16	2808	39	25
Battery shop	5400			540	10	22	432	8	22	540	10	11			
6. Rod and Wire Mill Cranes:															
Billet yard	7800	67	87	4300	55	27	2340	30	27	2730	35	17			
Rod mill	4300	80	115	3000	70	25	1300	30	25	1700	40	20			
Rod dock	8000	60	110	6400	80	70	4800	60	70	3200	40	50			
Cleaning house	8000	90	100	4800	60	100	1600	20	60	3200	40	90			
Pot annealing	6900	87	110	3800	55	85	2400	35	65	1700	25	30	5500	80	100
Rod storage	7300	94	96	4400	60	34	2200	30	34	700	10	34			
Patenting department	2900	90	94	1900	65	32	450	15	32	580	20	32			
Bar bending and storage	8000	60	110	6400	80	100	2400	30	50	3200	40	40			
7. Tube Mill Cranes:															
Hot mill	8000	90	140	4800	60	60	1600	20	60	2640	33	30			
Finishing mill	8400	80	115	5050	60	70	1700	20	70	2800	33	35			
Galvanizing	8400	75	115	5050	60	70	1700	20	70	2800	33	35			
8. Miscellaneous Cranes:															
Forging manipulators	5400	80	115	2480	46	33	2430	45	30	1134	21	18	108	2	1
Hydraulic forging cranes	8640	80	110	3630	42	17	3197	37	40	3024	35	22			
Warehouse	3960			1700	43	16	713	18	17	990	25	16			
Gantry	5040	70	90	2020	40	34	2268	45	81	2520	50	88			
Repair	1800	80	102	504	28	15	360	20	14	378	21	12	396	22	15
Machine shop	5040	80	90	2068	41	21	1310	26	21	1008	20	12	1512	30	18
Service	1800			610	34	11	288	16	12	450	25	14			
Power house	1080	90	115	270	27	8	270	27	13	260	24	7	230	21	13
Motor room	1080		110	240	22	4	162	15	6	194	18	4	162	15	4

and experience of those responsible for making the selection. Some of the factors affecting a selection of conductor size are:

1. Size of cable used previously for similar applications.
2. Ambient temperature or other surrounding condition.
3. Size of cable available.
4. Size and length of conduit run.
5. Number and kind of bends in conduit run.
6. Ampere rating of motor for the duty involved.
7. Compliance with the National Electrical Code, Chicago Electrical Code, or similar authority.

The above factors are not necessary listed in order of importance, as replacement of existing facilities may involve conditions not present when new installations are being considered. It is common practice to replace cables "in kind," if satisfactory service has been given over an appreciable time. Where failures have occurred and there are evidences of heating, conductors may be increased by one or more sizes. Ordinarily, in selecting cable sizes, the listed factors are weighed against code ratings for the type of insulation under consideration, and then tempered with past experience.

Such methods are difficult to reduce to definite specifications for controlling work to be done by crane or machinery builders, and by field installation forces. Also, it is likely that there will be as many different

TABLE II

Classification of Crane Service

Type of crane	Service							
	I	II	A—Average duty			B—Heavy duty		
	Indoor	Outdoor	1 Avg temp	2 High temp	3 Corrosion resistant	1 Avg temp	2 High temp	3 Corrosion resistant
1 Coke Plant and Blast Furnace Cranes:								
Drawing machine (coke pusher)		X					X	
Bucket handling		X				X		
Stock yard		X					X	
Slag handling		X						X
Scrap yard		X					X	
Cast house	X		X					
Pig machine	X			X				
Ladle house	X		X					
Skull cracker		X				X		
Sand house (bucket)	X		X					
Settling basin		X	X		X			
Car repair shop	X		X					
Ore bridge		X					X	
Coke ovens (coal bridge)		X					X	
2. Open Hearth, Electric Furnace, Bessemer Cranes:								
Charging machines	X						X	
Hot metal crane (charging)	X						X	
Ladle	X						X	
Metal mixer	X						X	
Electric furnace charging	X						X	
Stock yard		X				X		
Scrap preparation		X				X		
Scrap baler	X					X		
Scrap shear	X					X		
Hot top	X					X		
Bucket		X					X	
Slag handling		X					X	
Cinder yard		X					X	
Skull cracker		X				X		
General service	X	X	X					
3. Ingot Handling Cranes:								
Ingot handling		X				X		
Soaking pit	X						X	
Stripper	X						X	
Mold yard		X					X	
4. Rolling Mill Cranes:								
Slab yard	X					X		
Slab furnace charging	X						X	
Slab chargers overhead	X						X	
Plate and strip handling	X						X	
Billet mill	X		X			X		
Billet shipping	X					X		
Rail mill	X		X			X		
Rail loading dock	X	X	X			X		
Rail shipping	X	X				X	X	
Hot mill	X					X	X	
Cold strip mill	X					X		
Coil storage	X					X		
Roll shop	X		X					

Type of crane	Service							
	I	II	A—Average duty			B—Heavy duty		
	Indoor	Outdoor	1 Avg temp	2 High temp	3 Corrosion resistant	1 Avg temp	2 High temp	3 Corrosion resistant
Mill service	X					X		
Machine shop	X		X					
Cooling building	X					X		
Inspection and conditioning	X		X					
Pit cover	X					X		
5. Finishing Mill Cranes:								
Slab storage	X	X				X		
Charging machines	X					X		
Billet yard	X	X				X		
Furnace room	X						X	
Mill service	X					X		
Shipping	X					X		
Warehouse	X					X		
Stock	X		X					
Sorting room	X		X					
Shear	X					X		
Scale pits	X		X					
Hot bed	X			X			X	
Pickling	X					X		X
Quenching	X			X				
Tin mill	X						X	
Annealing	X						X	
Battery shop	X		X		X			
Scarfing	X					X		
6. Rod and Wire Mill Cranes:								
Billet yard	X					X		
Furnace skid charging	X		X					
Rod mill	X		X					
Rod dock		X				X		
Cleaning house	X					X		
Pot annealing	X					X		
Rod storage	X					X		
Patenting department	X		X					
Bar bending and storage	X					X		
Shipping	X					X		
7. Tube Mill Cranes:								
Hot mill	X						X	
Finishing mill	X					X		
Galvanizing	X							X
8. Miscellaneous Cranes:								
Forging manipulators	X						X	
Hydraulic forging	X						X	
Warehouse	X	X	X					
Gantry		X				X		
Repair	X		X					
Machine shop	X		X			X		
Service	X		X					
Weld shop	X		X					
Power house	X		X					
Coal lorry (boiler house)	X	X	X					
Motor room	X		X					

TABLE III

Typical Enclosed Mill Type Motor Ratings

Frame size	½ Hour		1 Hour		5 Hour	
	Hp	Amp	Hp	Amp	Hp	Amp
2	6.5	29	5	21	3.5	14
3	10	44	7.5	31	4.5	18
4	13.5	57	10	40	6	24
6	19	77	15	57	7.5	29
8	33	126	25	95	13	50
10	45	175	35	132	18	68
12	65	245	50	185	22.5	84
14	100	368	75	272	37	130
16	135	500	100	360	46	170
18	200	740	150	540	66	250
20	265	960	200	730	85	300
21	330	1200	250	900	105	390
22	465	1760	350	1290	140	500
23	645	2340	500	1810	200	717

specifications or standards as there are responsibilities for making up the specifications.

Motor and cable ratings—The foregoing conditions are due primarily to differences in rating. As illustrated in Tables III, IV, and V, mill type motors may be rated for various time interval duties. The ½-hour, 1-hour, 1-hour continuous—force ventilated, and 5-hour continuous ratings are most frequently encountered. All of these ratings are based on a 75C temperature rise from an ambient of 30C. Table V indicates that the ½-hour current ratings average 260 per cent of the 5-hour continuous ratings, and that the 1-hour current ratings average 190 per cent of the 5-hour continuous ratings. On the other hand, conductor cables are usually rated for continuous duty with various temperature rise values from an ambient of 30C, dependent upon the type of insulation, as shown in Table VI. However, the desirability of having short time conductor cable ratings comparable with short time motor current ratings has been recognized. Short time conductor cable ratings were developed experimentally during World War I by Henry C. Horstmann and Victor H. Tousley. Descriptions of their tests, experimental data, and conclusions, were developed in a series of articles "Investigation of Heating of Conductors" which, with editorial comment, were published in Electrical World in 1918. In 1919, the same authors published "Electrical

TABLE IV

Relation of Mill Type Motor Horse-Power Ratings
(The relation of horse-power ratings is emphasized. The ½-hour rating averages 250 per cent of the 5-hour continuous rating, and the 1-hour rating averages 190 per cent of the 5-hour continuous rating.)

Frame	1 ½-hr hp	2 1-hr hp	3 5-hr hp	4 ½-hr hp / 1-hr hp	5 ½-hr hp / 5-hr hp	6 1-hr hp / 5-hr hp	7 1-hr hp / ½-hr hp	8 5-hr hp / ½-hr hp
2	6.5	5	3.5	$\frac{6.5}{5}=1.30$	$\frac{6.5}{3.5}=1.86$	$\frac{5.0}{3.5}=1.43$	$\frac{5}{6.5}=0.77$	$\frac{3.5}{6.5}=0.55$
3	10	7½	4.5	$\frac{10}{7.5}=1.33$	$\frac{10.0}{4.5}=2.22$	$\frac{7.5}{4.5}=1.67$	$\frac{7.5}{10}=0.75$	$\frac{4.5}{10}=0.45$
4	13½	10	6	$\frac{13.5}{10}=1.35$	$\frac{13.5}{6.0}=2.25$	$\frac{10.0}{6.0}=1.67$	$\frac{10}{13.5}=0.74$	$\frac{6}{13.5}=0.46$
6	19	15	7.5	$\frac{19}{15}=1.27$	$\frac{13.0}{7.5}=2.53$	$\frac{15.0}{7.5}=2.00$	$\frac{15}{19}=0.79$	$\frac{7.5}{19}=0.39$
8	33	25	13	$\frac{33}{25}=1.32$	$\frac{33}{13}=2.54$	$\frac{25}{13}=1.92$	$\frac{25}{33}=0.76$	$\frac{13}{33}=0.39$
10	45	35	18	$\frac{45}{35}=1.29$	$\frac{45}{18}=2.50$	$\frac{35}{18}=1.95$	$\frac{35}{45}=0.78$	$\frac{18}{45}=0.40$
12	65	50	22.5	$\frac{65}{50}=1.30$	$\frac{65.0}{22.5}=2.89$	$\frac{50.0}{22.5}=2.22$	$\frac{50}{65}=0.77$	$\frac{22.5}{65}=0.35$
14	100	75	37	$\frac{100}{75}=1.33$	$\frac{100}{37}=2.70$	$\frac{75}{37}=2.03$	$\frac{75}{100}=0.75$	$\frac{37}{100}=0.37$
16	135	100	47	$\frac{135}{100}=1.35$	$\frac{135}{47}=2.88$	$\frac{100}{47}=2.13$	$\frac{100}{135}=0.74$	$\frac{47}{135}=0.35$
18	200	150	68	$\frac{200}{150}=1.33$	$\frac{200}{68}=2.94$	$\frac{150}{68}=2.21$	$\frac{150}{200}=0.75$	$\frac{68}{200}=0.37$
Weighted averages	.....	.....	.....	$\frac{13.17}{10}=1.32$	$\frac{25.21}{10}=2.52$	$\frac{19.23}{10}=1.92$	$\frac{7.60}{10}=0.76$	$\frac{2.59}{7}=0.37$

TABLE V

Relation of Mill Type Motor Current Ratings

(The ½-hour current averages 260 per cent of the 5-hour continuous rating, and the 1-hour current averages 190 per cent of the 5-hour continuous rating. For most practical purposes, the relation of motor current ratings may be assumed to be in the same ratio as motor horse-power ratings without serious error.)

Frame	1 Amp ½-hr	2 Amp 1-hr	3 Amp 5-hr	4 Col. 1 divided by Col. 3	5 Col. 2 divided by Col. 3
2	29	21	14	2.07	1.50
3	44	31	18	2.44	1.72
4	57	40	24	2.39	1.66
6	77	57	29	2.67	1.97
8	126	95	50	2.52	1.90
10	175	132	68	2.58	1.94
12	245	185	84	2.92	2.10
14	368	272	130	2.83	2.09
16	500	360	170	2.94	2.11
18	740	540	250	2.96	2.16
20	960	730	420	2.28	1.74

Weighted average column 4 = 2.6
Weighted average column 5 = 1.9

Motor Control Systems and Methods," which included a chapter entitled "Carrying Capacities of Wires for Short Time Periods and Intermittent Loads," based largely on the articles published in Electrical World.

Horstmann and Tousley tests—continuous ratings—The following is taken in part from the articles in Electrical World.

"The authors of this series of articles have attempted to set down in concise usable form the results of experiments made to determine exactly the heating effects of current on wires under continuous load and limited time ratings.

"The steady current which will produce a given ultimate temperature rise in a conductor can be found by the formula $I = \sqrt{KC}$, in which K is a constant and C the temperature rise above the surrounding air in degrees centigrade. The constants for the various wire sizes here considered are deduced from heating curves experimentally obtained in the laboratory of the Commonwealth Edison Company of Chicago, where the tests were made, at the suggestion of the Department of Gas and Electricity of that city. The constants were obtained by dividing the square of the current used in connection with individual tests by the rise in temperature produced in the conductor. Several sets of constants are given, some of them applying to ultimate temperature rise and others for shorter lengths of time. The tests were made jointly by engineers of the above company and the Bureau of Electrical Inspection.

"The method used was as follows: Sections of wire or cable were looped three times through a 10-ft (3.05 m) length of conduit pipe. Under these conditions the three conductors within the pipe were heated by the same current. The conduit pipes were supported

TABLE VI

Allowable Current Carrying Capacities in Accordance with the 1947 National Electrical Code Based on Room Temperature of 30 C or 86 F

(These data are code ratings tabulated here for ready reference. In addition to the conventional ratings, some 80 and 110 per cent ratings have been calculated and included.)

Size AWG or MCM	Not more than three conductors in raceway or cable							Single conductors in free air			
	1 R and T 60 C	2 Col. 1 x 0.8	3 Col. 1 +10%	4 RH 75 C	5 Col. 4 x 0.8	6 Col. 4 +10%	7 ½-1 hr R - 60 C	8 R and T 60 C	9 Col. 7 +10%	10 RH 75 C	11 Col. 9 +10%
14	15	12	16	15	12	16	20	20	22	20	22
12	20	16	22	20	16	22	25	25	27	25	27
10	30	24	33	30	24	33	35	40	44	40	44
8	40	32	44	45	36	49	45	55	60	65	71
6	55	44	60	65	52	71	57	80	88	95	104
5							65				
4	70	56	77	85	68	93	77	105	115	125	137
3	80	64	88	100	80	110	90	120	132	145	160
2	95	76	104	115	92	126	107	140	154	170	187
1	110	88	121	130	104	143	130	165	182	195	212
1/0	125	100	137	150	120	165	160	195	212	230	253
2/0	145	116	160	175	140	192	195	225	247	265	291
3/0	165	132	182	200	160	220	245	260	286	310	341
4/0	195	156	212	230	184	253	300	300	330	360	396
250	215	172	237	255	204	280	350	340	374	405	445
300	240	192	264	285	238	314	410	375	412	445	490
350	260	208	286	310	248	341	460	420	462	505	555
400	280	224	308	335	268	368	515	455	500	545	600
500	320	256	352	380	304	418	620	515	566	620	682
600	355	284	390	420	334	462		575	632	690	759
700	385	308	425	460	368	506		630	693	755	830
750	400	320	440	475	378	522		655	720	785	863
800	410	328	460	490	392	540		680	748	815	896
900	435	348	478	520	416	572		730	803	870	957
1000	455	364	500	545	436	600		780	860	935	1028

3½ ft (1.06 m) above the floor by means of wooden horses placed at each end. Thermocouples were placed directly in contact with the copper, with as little disturbance to the insulation as possible, and were installed in the center of the conduit. The current was furnished by large-capacity, low voltage storage batteries and was maintained constant by means of adjustable resistance. A potentiometer indicator was used to determine the difference in temperature. The formula given above is strictly correct only for the ultimate temperatures obtained experimentally, and if other temperatures are to be considered and great accuracy is required, corrections for increased resistance with increased temperatures should be made."

The foregoing indicates that the investigation began with a study of ultimate temperature continuous current capacity ratings based on the 1918 code ratings. At that time, rubber covered conductors were limited to a maximum operating temperature of 50C. With an ambient temperature of 30C, the temperature rise permissible was 20C. Table VII shows that the actual temperature rise when carrying code rated current ranged from 15 to 23.2C for sizes No. 14 to 2/0. The 500 MCM cable with a temperature rise of 26.7C appreciably exceeded the maximum operating temperature. The 4/0 cable, the least conservatively rated of those tested, had a temperature rise of 32C. Table VII also lists the actual current carrying capacities when the temperature rise was limited to 10C, 20C, 30C, and 40C. In Table VII-A, a comparison is made between the 1918 code, Horstmann and Tousley, and 1947 code ratings. It will be observed that the 1947 code ratings for 30C and 45C rise are more conservative than the H&T test ratings are for 30C and 40C rise.

Horstmann and Tousley tests—limited time ratings —The following is quoted from the articles in Electrical World:

"Since motors are given short time ratings, there ap-

TABLE VII

Carrying Capacity of Rubber Covered Conductors

(This table is compiled from "Investigation of Heating of Conductors" by Horstmann & Tousley in September 1918 issue of Electrical World.)

Ultimate-Temperature Constants for Rubber-Covered Conductors

Size AWG or MCM	Carrying capacity N.E. code	In conduit			Open			
		K	Temp rise	Time, minutes	K	Temp rise	Time, minutes	Temp outer braid
14	15	15	15	80	34	6.5	40	3.6
12	20	23.2	17.2	60	61	6.2	20	4.3
10	25	40.3	15.5	55	88	7.0	30	4.3
8	35	73.8	16.6	85	155	9.5	40	6.0
6	50	136.0	18.4	95	291	8.3	30	6.0
4	70	217.0	22.6	110	442	12.0	35	7.1
3	80	333.0	19.2	100	666	9.6	50	6.6
2	90	422.0	19.2	100	898	9.2	60	6.2
1	100	467.0	21.4	110	1,165	9.2	50	7.2
1/0	125	684.0	22.8	250	1,768	8.8	50	6.0
2/0	150	969.0	23.2	150	2,079	11.4	60	6.2
3/0	175	1,392.0	22.0	200	2,992	9.8	60	8.2
4/0	225	1,582.0	32.0	215	3,616	14.0	60	....
300	275	2,832.0	26.7	240	5,954	12.7	80	....
400	325	3,956.0	26.7	240	8,316	12.7	90	....
500	400	5,992.0	26.7	240	12,252	12.7	100	....

Carrying Capacity of Various-Size Rubber-Covered Conductors

Size AWG or MCM	In conduit				Open			
	10 C	20 C	30 C	40 C	10 C	20 C	30 C	40 C
14	12	17	21	24	18	26	32	34
12	15	21	26	30	24	34	42	43
10	20	28	35	40	29	45	51	57
8	27	38	47	54	39	55	68	72
6	36	52	63	73	54	76	93	94
4	46	65	80	93	66	94	114	125
3	57	81	99	115	81	115	141	145
2	65	91	112	129	94	134	164	168
1	69	96	118	135	107	151	186	195
1/0	82	117	143	165	133	188	230	225
2/0	98	139	170	197	144	203	249	260
3/0	118	167	204	236	172	244	291	300
4/0	126	178	218	250	190	268	328	350
300	168	238	291	335	245	342	422	450
400	198	281	345	415	288	406	498	560
500	245	346	424	490	348	490	602	670

TABLE VII-A

Comparison of Various Continuous Carrying Capacity and Temperature Rise Ratings
(This table indicates that the 1947 code ratings for type RH-45 C rise cable are more conservatively rated than the Horstmann & Tousley rating for 40 C rise.)

Size AWG or MCM	1918 N.E. code amp	Temp rise C	H&T amp 20 C rise	H&T amp 30 C rise	H&T amp 40 C rise	1947 N.E. code, amp 30 C rise. Type R-60 C	1947 N.E. code, amp 45 C rise. Type RH-75 C
14	15	15.0	17	21	24	15	15
12	20	17.2	21	26	30	20	20
10	25	15.5	28	35	40	30	30
8	35	16.6	38	47	54	40	45
6	50	18.4	52	63	73	55	65
5	....	....	....	....	80	....	....
4	70	22.6	65	80	93	70	85
3	80	19.2	81	99	115	80	100
2	90	19.2	91	112	129	95	115
1	100	21.4	96	118	135	110	130
1/0	125	22.8	117	143	165	125	150
2/0	150	23.2	139	170	197	145	175
3/0	175	22.0	167	204	236	165	200
4/0	225	32.0	178	218	250	195	230
300	275	26.7	238	291	335	240	285
400	325	26.7	281	345	398	280	335
500	400	26.7	346	424	490	320	380

pears to be no reason why the feeding wires should not be given higher ratings for short time loads than those given to them for continuous loads. The horsepower rating of a motor depends usually upon the temperature rise caused by the current necessary to develop the required torque and speed. Thus a motor which has a 100-hp rating for continuous service may be given several times this rating provided that it will not be called upon to develop this horsepower for any great length of time. Since such a motor can be used only for short intervals, and as it does not cool so rapidly as the conductors which feed it, it seems reasonable to give the conductors the same rating as the motor. In other words, they should not be required to have a capacity sufficient to carry the motor current continuously.

"The current in amperes which will cause a certain temperature rise in a given conductor in a fixed time can be found by the formula $I = i\sqrt{(T/t)}$, where T equals the limiting temperature, t the temperature rise caused in the conductor by the current i in the time given, and I the current which will cause the rise to T degrees above the surrounding air." The values of t corresponding to the various sizes of wire and length of time considered are given in Table VIII and represent the temperature rises caused by the currents in amperes given in column i at the left.

The current given is that authorized by the National Electrical Code, and the values of t have all been experimentally obtained with the exception of those given for 300,000-circular mil and 400,000 circular mil cables. The figures given for these cables are based on the assumption that the carrying capacities given are in proper proportion.

In Table VIII the currents permissible for short-time use have been calculated according to the formula given and for a temperature rise of 20C. As in previous tables, no attempt has been made to make corrections for change in resistance with temperature.

Table VIII tabulates the temperature rise constant (t) for intervals of 5, 10, 15, 20, 25, 30, 40, 50, and 60 minutes. Using those constant values, current carrying ratings have been computed for 20C temperature rise.

Horstmann and Tousley tests—current carrying capacity tables—Tables IX, X, XI, and XII give Horstmann and Tousley ratings as published in 1919 in their book, "Electric Motor and Control Systems and Methods." These tables give the prevailing code ratings and the experimentally developed ratings for indefinite time (continuous), 60, 30, 15, 10, and 5 minute intervals. Both open wiring and conduit wiring for three conductors are covered for 20C and 40C temperature rise conditions.

Table XIII develops a comparison between indefinite time (continuous) one hour, and half hour ratings taken from the various tables given Horstmann and Tousley ratings. It will be observed that the one hour ratings average 114 per cent of the continuous ratings, and the half hour ratings average 136 per cent of the continuous ratings.

Although the work done by Horstmann and Tousley was published in 1918 and 1919, it was not until 1947 that the National Electrical Code, in Article 610, Cranes and Hoists, covered 60C conductor ratings for 5-15 minute ratings, and for 30-60 minute ratings. The 30-60 minute ratings have been included in Table VI, Column 7, and in Table XIV, Column 1. Table XIV has been prepared to give a comparison between various 1947 code and Horstmann and Tousley ratings for 60C and 75C rubber covered conductors. Table XV gives a similar comparison for asbestos varnished cambric asbestos (AVA) 110C conductors.

An analysis of the tables thus far indicates that the ½-hour conductor cable in conduit ratings range from 109 per cent for No. 14 to 173 per cent of the continuous rating for 500 MCM, with an overall average of 136 per cent. This compares with an average of 260 per

cent for similarly rated mill type motors. The one hour conductor cable in conduit ratings range from 104 per cent for No. 14 to 134 per cent of the continuous rating for 500 MCM, with an overall average of 114 per cent. This compares with an average of 190 per cent for similar rated mill type motors. From this it is concluded that the practice of selecting code continuous rated conductors based on the continuous motor current ratings will result in unsafe and unsatisfactory conductor cable and conduit systems, if the motors are actually used at the ½-hour or 1-hour current rating, and will require replacement. The replacement of such systems under adverse operating conditions is an expensive and time consuming procedure.

Likewise, the selection of code continuous rated conductors based on the ½-hour or 1-hour motor current ratings will result in larger conductor cable and conduit systems than are necessary to obtain safe satisfactory performance. This is particularly true of the larger size motor applications where space is limited, and clearances are critical.

MILL MOTOR FRAME LEAD DATA

Because of the wide range of current ratings of mill type motors, the sizes of around-the-frame motor leads are of interest in determining conduit wiring cable size standards. Tables XVI and XVII have been developed to compare the three mill motor manufacturer's standard lead sizes with those used by a typical steel plant. In Table XVIII those lead sizes are compared with various conductor cable sizes.

Analysis of Tables XVI, XVII, and XVIII lead to the following:

1. There is some disparity in motor frame lead sizes

TABLE VIII

Carrying Capacity of Rubber Covered Conductor
(This table is compiled from "Investigation of Heating of Conductors" by Horstmann & Tousley in September 1918 issue of Electrical World.)

Short time temperature constant (t) for rubber covered conductors

Size AWG or MCM	Time in minutes									
	i	5	10	15	20	25	30	40	50	60
14	15	5.2	7.6	9.4	10.5	11.4	12.1	13.3	14.0	14.6
12	20	6.4	9.4	11.6	13.0	14.2	15.0	16.2	16.8	17.2
10	25	5.6	8.2	10.0	11.6	12.6	13.5	14.7	15.4	15.6
8	35	5.6	8.0	9.7	11.0	12.2	13.0	14.2	15.2	15.9
6	50	3.8	6.9	9.2	10.8	12.1	13.2	14.8	16.1	17.1
4	70	4.6	7.2	9.3	11.3	12.9	14.3	16.5	18.1	19.5
3	80	4.2	6.6	8.4	10.0	11.5	12.8	15.0	16.4	17.5
2	90	4.0	6.4	8.5	10.1	11.5	12.6	14.6	16.1	17.2
1	100	3.2	6.0	8.3	10.1	11.6	12.8	14.8	16.6	18.2
1/0	125	2.4	4.9	6.8	8.5	10.0	11.5	14.0	15.8	17.2
2/0	150	4.0	6.4	8.2	9.9	11.4	12.6	14.9	16.8	18.3
3/0	175	2.8	5.0	6.7	8.2	9.4	10.5	12.4	14.0	15.4
4/0	225	3.2	6.0	8.5	11.0	13.0	14.8	18.1	20.8	23.2
300	275	1.9	3.6	5.0	6.3	7.7	8.9	11.0	13.0	14.6
400	325	1.9	3.6	5.0	6.3	7.7	8.9	11.0	13.0	14.6
500	400	1.9	3.6	5.0	6.3	7.7	8.9	11.0	13.0	14.6

Rubber Covered Conductors

Current ratings for 20 C temperature rise

Size AWG or MCM	Time rating of motor in minutes									
	i	5	10	15	20	25	30	40	50	60
14	15	29.4	24.3	21.9	20.7	19.8	19.2	18.3	18.0	17.5
12	20	35.4	29.2	26.2	24.8	23.8	23.0	22.2	21.8	21.6
10	25	47.2	39.0	35.2	32.7	31.5	30.5	29.0	28.5	28.2
8	35	66.1	55.3	50.0	47.2	44.8	43.4	41.6	39.9	39.2
6	50	114.0	85.0	73.5	68.0	64.0	61.5	58.0	55.6	54.0
4	70	145.6	116.9	102.2	93.1	86.8	82.6	77.0	73.5	70.7
3	80	174.4	139.2	123.2	112.8	105.6	100.0	92.0	88.0	85.6
2	90	200.7	159.3	137.7	127.0	118.8	113.4	105.3	104.4	97.2
1	100	250.0	182.0	155.0	141.0	131.0	125.0	116.0	109.5	104.8
1/0	125	360.0	252.5	213.7	191.2	176.2	165.0	148.7	145.0	133.7
2/0	150	334.5	264.0	234.0	213.0	128.0	189.0	174.0	163.5	154.2
3/0	175	463.7	350.0	302.7	273.0	255.5	241.5	222.2	209.2	199.5
4/0	225	562.0	409.5	344.2	303.7	279.0	261.0	236.2	220.5	207.0
300	275	891.0	649.0	550.0	483.5	442.7	412.5	371.2	341.0	280.0
400	325	1053.0	767.0	650.0	578.5	523.2	487.5	438.7	403.0	331.5
500	400	1296.0	944.0	800.0	712.0	644.0	600.0	540.0	496.0	408.0

TABLE IX

Table of Carrying Capacities, Three Conductors in Conduit, Each Carrying the Same Current, for 40 C Temperature Rise
(This table is taken from Horstmann & Tousley's "Electric Motor and Control Systems and Methods" published in 1919. The temperature when carrying rated code current is shown. Current ratings for time intervals of 5, 10, 15, and 30 minutes have been taken from the aforementioned book. The 60 minute ratings were taken from previous data given by the authors and inserted into these tables for use in developing proposed standards. Special attention is called to the differences in rating for a given conductor size in the ½-hour, 1-hour, indefinite time, and continuous classifications.)

Size AWG MCM	Size conduit, in.	N.E. code		Calculated carrying capacities 40 C rise					
		Carrying capacity, amp	Temp rise, degree C	Indefinite time, amp	Short time in minutes				
					60	30	15	10	5
14	½	15	15.0	24	25	26	31	34	42
12	¾	20	17.2	30	30	33	37	41	50
10	¾	25	15.5	40	40	43	50	55	65
8	1	35	16.6	54	55	60	70	85	95
6	1	50	18.3	73	76	86	105	115	150
5	.....	55	.....	80	85	95	125	140	180
4	1¼	70	22.6	93	100	117	140	155	200
3	1¼	80	19.4	115	120	141	150	190	235
2	1½	90	19.3	129	137	160	175	220	275
1	1½	100	21.7	135	143	175	215	250	315
1/0	2	125	22.8	165	190	233	255	290	385
2/0	2	150	23.2	197	222	267	310	360	440
3/0	2	175	21.9	236	280	341	380	430	565
200	.....	200	.....	240	.....	350	430	520	675
4/0	2½	225	32.0	250	295	369	455	550	720
250	.....	240	.....	280	364	420	525	640	820
300	3	275	25.1	335	455	582	610	750	965
350	.....	300	.....	375	486	646	700	845	1105
400	3	325	23.4	415	538	688	775	965	1190
500	3	400	26.8	490	660	847	925	1130	1520
600	.....	450	.....	545	.....	900	1050	1280	1700
700	.....	500	.....	600	.....	950	1160	1435	1960
750	4	525	24.9	630	.....	1020	1220	1510	2030
800	.....	550	.....	660	.....	1050	1260	1560	2135
900	.....	600	.....	700	.....	1140	1365	1690	2330
1000	4½	650	30.7	740	.....	1215	1460	1840	2520

TABLE X

Table of Carrying Capacities, Three Conductors in Conduit, Each Carrying the Same Current, for 20 C Temperature Rise
(This table is similar to Table IX except for 20 C temperature rise.)

Size AWG MCM	Size conduit, in.	N.E. code		Calculated carrying capacities 20 C rise					
		Carrying capacity, amp	Temp rise, degree C	Indefinite time, amp	Short time in minutes				
					60	30	15	10	5
14	½	15	15.0	17	18	19	22	24	30
12	¾	20	17.2	21	22	24	26	29	35
10	¾	25	15.5	28	28	30	35	40	45
8	1	35	16.6	38	39	43	50	60	65
6	1	50	18.4	52	54	60	73	80	105
5	.....	55	.....	56	.....	69	88	100	125
4	1¼	70	22.6	65	71	82	97	110	140
3	1¼	80	19.2	81	86	100	113	135	165
2	1½	90	19.2	91	97	113	130	155	195
1	1½	100	21.4	96	105	126	154	180	225
1/0	2	125	22.8	117	134	165	182	210	275
2/0	2	150	23.2	139	157	189	220	260	340
3/0	2	175	22.0	167	200	241	270	320	420
200	.....	200	.....	175	.....	247	310	355	480
4/0	2½	225	32.0	178	209	261	325	395	515
250	.....	240	.....	205	.....	297	375	455	585
300	3	275	25.1	238	322	412	435	535	690
350	.....	300	.....	265	.....	460	500	605	790
400	3	325	23.4	281	380	487	555	690	850
500	3	400	26.8	346	468	600	660	800	1090
600	.....	450	.....	390	.....	675	750	915	1225
700	.....	500	.....	430	.....	680	830	1025	1400
750	4	525	24.9	450	.....	710	870	1080	1450
800	.....	550	.....	465	.....	745	905	1120	1525
900	.....	600	.....	495	.....	810	975	1210	1665
1000	4½	650	30.7	525	.....	870	1040	1295	1800

TABLE XI

Table of Carrying Capacities, Open Wires, for 40 C Temperature Rise
(This table is similar to Table IX except for open wires.)

Size AWG MCM	N.E. code		Calculated carrying capacities 40 C rise					
	Carrying capacity, amp	Temp rise, degree C	Indefinite time, amp	Short time in minutes				
				60	30	15	10	5
14	20	14.4	34	.....	34	40	46	52
12	25	10.6	43	.....	43	54	59	65
10	30	10.0	57	.....	57	67	74	83
8	50	15.5	72	.....	72	84	92	103
6	70	16.4	94	.....	94	109	122	134
5	80	.....	110	.....	110	127	141	157
4	90	17.8	125	.....	125	145	165	190
3	100	14.5	145	.....	145	175	202	234
2	125	17.0	168	.....	170	205	245	295
1	150	18.0	195	.....	205	250	309	372
1/0	200	22.2	225	.....	235	300	360	460
2/0	225	22.9	260	.....	290	350	430	530
3/0	275	25.4	300	.....	345	410	520	645
200	300	.....	335	.....	400	480	610	750
4/0	325	31.1	350	.....	410	500	630	785
250	350	.....	400	.....	470	575	730	925
300	400	21.1	450	.....	550	660	860	1070
350	450	.....	500	.....	630	760	980	1250
400	500	26.1	560	.....	700	840	1100	1425
500	600	28.7	670	.....	840	1025	1330	1785
600	680	.....	780	.....	965	1200	1550	2190
700	760	.....	870	.....	1080	1370	1760	2500
750	800	31.7	910	.....	1110	1435	1860	2675
800	840	.....	950	.....	1190	1525	1960	2855
900	920	.....	1020	.....	1300	1665	2150	3215
1000	1000	30.0	1085	.....	1400	1800	2330	3500

TABLE XII

Table of Carrying Capacities, Open Wires, for 20 C Temperature Rise
(This table is similar to Table X except for open wires.)

Size AWG MCM	N.E. code		Calculated carrying capacities 20 C rise					
	Carrying capacity, amp	Temp rise, degree C	Indefinite time, amp	Short time in minutes				
				60	30	15	10	5
14	20	14.4	25	.....	25	29	33	37
12	25	10.6	31	.....	31	39	42	47
10	30	10.0	41	.....	41	47	53	60
8	50	15.5	52	.....	52	60	66	75
6	70	16.4	67	.....	67	80	87	95
5	80	.....	80	.....	80	90	100	112
4	90	17.8	90	.....	90	105	120	137
3	100	14.5	100	.....	100	125	145	168
2	125	17.0	120	.....	120	150	175	210
1	150	18.0	140	.....	145	180	220	265
1/0	200	22.2	160	.....	165	215	260	330
2/0	225	22.9	186	.....	210	250	310	380
3/0	275	25.4	215	.....	250	300	380	465
200	300	.....	240	.....	290	345	440	535
4/0	325	31.1	250	.....	300	360	450	560
250	350	.....	285	.....	335	410	520	660
300	400	21.1	325	.....	400	475	620	765
350	450	.....	360	.....	450	545	700	895
400	500	26.1	400	.....	500	600	780	1020
500	600	28.7	480	.....	600	730	950	1220
600	680	.....	560	.....	690	860	1110	1565
700	760	.....	625	.....	775	970	1260	1785
750	800	31.7	650	.....	800	1025	1340	1910
800	840	.....	680	.....	850	1090	1400	2040
900	920	.....	730	.....	930	1190	1550	2300
1000	1000	30.0	775	.....	1000	1285	1665	2500

TABLE XIII

Relation of Indefinite Time, 1-Hour, and ½-Hour Current Capacity Ratings Based on Data Shown in Table IX
(These data are developed to show the relative increase in capacity, with increase in size, for conductors rated ½-hour and 1-hour.)

Size AWG MCM	1 Indefinite time, amp 40 C rise	2 1 Hour, amp 40 C rise	3 ½ Hour, amp 40 C rise	4 Col. 2 divided by Col. 1	5 Col. 4 group average	6 Col. 3 divided by Col. 1	7 Col. 6 group average
14	24	25	26	1.04		1.09	
12	30	30	33	1.00		1.10	
10	40	40	43	1.00	1.02	1.07	1.11
8	54	55	60	1.02		1.11	
6	73	76	86	1.04		1.18	
5	80	85	95	1.06		1.19	
4	93	100	117	1.08		1.26	
3	115	120	141	1.04	1.06	1.23	1.24
2	129	137	160	1.06		1.24	
1	135	143	175	1.06		1.29	
1/0	165	190	233	1.15		1.41	
2/0	197	222	267	1.13		1.36	
3/0	236	280	341	1.18	1.16	1.44	1.42
4/0	250	295	369	1.18		1.48	
250	280	364	420	1.30		1.50	
300	335	455	582	1.35		1.72	
350	375	486	646	1.30	1.32	1.72	1.66
400	415	538	688	1.29		1.65	
500	490	660	847	1.34		1.73	
				Col. 4 weighted Average = 1.14		Col. 6 weighted Average = 1.36	

Column 4 weighted average indicates that the 1-hour rating is 14 per cent greater than the continuous rating.
Column 6 weighted average indicates that the ½-hour rating is 36 per cent greater than the continuous rating.

TABLE XIV

Comparison of Various Short Time and Continuous Current Capacities
(These data are a compilation of continuous and short time current capacities taken from Tables IX and XIII to compare code and Horstmann & Tousley ratings. The ratio of increased capacity of code ½ and 1-hour ratings over continuous ratings for 60 C type R conductors are applied to 75 C type RH conductors for comparison.)

Size AWG MCM	1 Amp 1947 code ½-1 hr rating R-60 C	2 Amp 1947 code 3 condrs in conduit R-60 C	3 Amp 1947 code 3 condrs in conduit RH-75 C	4 Amp 1947 code ½-1 hr 4-6 condrs in conduit R-60 C	5 Amp 1947 code 4-6 condrs in conduit R-60 C	6 Amp 1947 code 4-6 condrs in conduit RH-75 C	7 ½-1 hr factors Col. 1 divided by Col. 2	8 Amp Col. 3 times Col. 7	9 Ratio RH/R Col. 3 divided by Col. 2
14	20	15	15	16	12	12	1.33	20	1.00
12	25	20	20	20	16	16	1.25	25	1.00
10	35	30	30	28	24	24	1.17	35	1.00
8	45	40	45	36	32	36	1.13	50	1.12
6	57	55	65	46	44	52	1.03	67	1.18
5	65	60	72	52	48	58	1.08	78	1.21
4	77	70	85	61	56	68	1.10	93	1.21
3	90	80	100	72	64	80	1.12	112	1.25
2	107	95	115	85	76	92	1.12	138	1.21
1	130	110	130	104	88	104	1.18	153	1.18
1/0	160	125	150	128	100	120	1.28	192	1.20
2/0	195	145	175	155	116	140	1.34	234	1.20
3/0	245	165	200	195	132	160	1.48	296	1.21
4/0	300	195	230	240	155	183	1.54	354	1.18
250	350	215	255	280	172	203	1.63	415	1.18
300	410	240	285	327	191	227	1.71	486	1.19
350	460	260	310	367	207	247	1.77	547	1.19
400	515	280	335	412	224	269	1.84	616	1.20
500	620	320	380	495	255	303	1.94	736	1.18

Correction Factor for Room Temperatures Over 30 C-86 F

Temp C	Temp F						
40	104	0.82	0.82	0.88	0.82	0.82	0.88
45	113	0.71	0.71	0.82	0.71	0.71	0.82
50	122	0.58	0.58	0.75	0.58	0.58	0.75
55	131	0.41	0.41	0.67	0.41	0.41	0.67
60	140	.....	.....	0.58	.....	.....	0.58

furnished by the three mill motor manufacturers. Inquiry at several plants has indicated that some difficulty has been experienced with motor frame leads, requiring replacement with sizes larger than those originally furnished. It is believed that the standardization of motor frame lead sizes should be referred to the AISE Mill Motor Standardization Committee. With the standardization of both the motor frame lead sizes and the conductor cable sizes, the standardization of lug connections can also be effected. This latter activity is one of the items on the agenda of the crane wiring committee slated for future action and no data is available for this report.

2. Although the ampere capacity assumed for the frame lead sizes may seem to be rather low for AVA-110C cable, it would appear that the temperature rise in the conductors due to the conductors carrying current will approximate 40C or more. With a probable ambient of 80C or more temperature inside the motor frame, the actual conductor temperature will approximate 40C + 80C = 120C. Therefore, the ratings should be considered on the conservative side.

3. The results of the study of these three tables lead to the formation of Table XIX, which sets the basic pattern for the proposed standards which follow.

TABLE XIV — Continued

Comparison of Various Short Time and Continuous Current Capacities

10 Amp H&T ½-hr rating 75 C	11 Amp H&T 1 hr rating 75 C	12 Amp H&T indefinite time rating 75 C	13 Col. 10 divided by Col. 12	14 Col. 11 divided by Col. 12	15 Col. 10 divided by Col. 11	16 Col. 15 times Col. 1	17 Col. 10 divided by Col. 3	18 Col. 11 divided by Col. 3	19 Col. 12 divided by Col. 3
26	25	24	1.09	1.04	1.04	0.20	1.73	1.67	1.60
33	30	30	1.10	1.00	1.10	0.27	1.65	1.50	1.50
43	40	38	1.07	1.05	1.08	0.37	1.43	1.33	1.27
60	55	50	1.11	1.10	1.09	0.49	1.33	1.22	1.11
86	76	70	1.18	1.08	1.13	0.64	1.32	1.17	1.07
95	85	80	1.19	1.06	1.12	0.72	1.32	1.18	1.11
117	100	90	1.26	1.11	1.17	0.90	1.38	1.18	1.06
141	120	110	1.23	1.09	1.17	0.105	1.41	1.20	1.10
160	137	125	1.24	1.09	1.17	0.125	1.39	1.19	1.08
175	143	135	1.29	1.06	1.22	0.160	1.34	1.10	1.04
233	190	165	1.41	1.25	1.22	0.196	1.55	1.26	1.10
267	222	197	1.35	1.13	1.20	0.234	1.53	1.27	1.12
341	280	215	1.44	1.30	1.22	0.300	1.70	1.40	1.08
369	295	250	1.48	1.18	1.25	0.375	1.60	1.28	1.09
420	364	280	1.50	1.52	1.15	0.402	1.64	1.42	1.10
582	455	335	1.72	1.31	1.28	0.525	2.04	1.60	1.17
646	486	375	1.72	1.30	1.33	0.612	2.06	1.57	1.21
688	538	415	1.65	1.25	1.28	0.660	2.04	1.59	1.24
847	660	480	1.73	1.33	1.28	0.795	2.23	1.74	1.26

BASIC DATA FOR PROPOSED STANDARDS

Table XIX has been developed from Table XVII. Two types of service are provided for, heavy and average duty, based on the classifications determined in Table II. For heavy duty service, ½-hour conductor cable ratings are applied to ½-hour motor current ratings. For average duty service, 1-hour conductor cable ratings are applied to 1-hour motor current ratings. The use of 1-hour motor current ratings for average duty service arbitrarily applies a load factor of 75 per cent, based on the ratio of the 1-hour and ½-hour ratings as developed in Table IV, Column 7. It will also be noted that No. 8 has been selected as an arbitrary minimum size conductor table. This size is based on mechanical considerations of strength and resistance to damage rather than electrical current capacity. In the interests of standardization and simplification, but two types of insulation are shown, moisture resistant 75C type RH insulation with neoprene covering, and AVA 110C asbestos varnished cambric insulation with asbestos covering impregnated with moisture resistant compound.

Table XX has been prepared to give some comparisons of motor lead sizes, proposed standard conductor cable sizes, and 1947 code sizes, developed from preceding tables. In addition, a tabulation of sizes used by three crane builders and a typical steel plant are included. It will be noted that there is a wide range in sizes between the 1947 code continuous ratings for 60C conductors, and those listed for Crane Builder "C." As a matter of interest, the proposed sizes listed for heavy duty service follow very closely the sizes listed for the typical steel plant.

PROPOSED STANDARDS

In line with the data considered in the various tables, the proposed standards cover mill type motors and the

TABLE XV

Comparison of Current Carrying Capacities for Type AVA 110 C Cable

(This table is similar to Table XIV, and applies some of the factors developed in that table to AVA conductors.)

Size AWG MCM	1 3 Condrs in conduit	2 Col. 1 +10%	3 4-6 Condrs Col. 1 times 0.8	4 7-9 Condrs Col. 1 times 0.7	5 1 Condr free air	6 Col. 5 times 0.61 80 C ambient	7 Short time factors from Table XIV, Col. 7	8 Col. 7 times Col. 1	9 ½-Hour factors Table XIV, Col. 17	10 Col. 9 times Col. 1 modified ½-hour ratings	11 1-Hour factors Table XIV, Col. 18	12 Col. 11 times Col. 1 modified 1-hour ratings	13 Modified continuous factors Table XIV, Col. 19	14 Col. 13 times Col. 1 modified continuous ratings
14	28	30	22	19	39	23	1.33	37	1.73	48	1.67	47	1.60	45
12	36	39	28	26	51	31	1.25	45	1.65	59	1.50	54	1.50	54
10	47	51	37	33	65	40	1.17	55	1.43	67	1.33	62	1.27	60
8	60	66	48	42	85	51	1.13	67	1.33	80	1.22	73	1.11	66
6	80	88	64	56	119	72	1.03	82	1.32	105	1.17	93	1.07	85
5	94	103	75	66	136	83	1.08	101	1.32	124	1.18	111	1.11	104
4	107	117	85	75	158	96	1.10	117	1.38	147	1.18	126	1.06	113
3	121	133	97	84	182	110	1.12	135	1.41	170	1.20	145	1.10	133
2	137	151	110	96	211	128	1.12	153	1.39	190	1.19	163	1.08	148
1	161	177	129	112	247	150	1.18	190	1.34	215	1.10	177	1.04	167
1/0	190	209	152	133	287	175	1.28	243	1.55	294	1.26	239	1.10	209
2/0	217	238	174	152	331	202	1.34	291	1.53	331	1.27	275	1.12	243
3/0	243	267	195	170	384	234	1.48	360	1.70	413	1.40	339	1.08	262
4/0	275	302	220	195	446	272	1.54	423	1.60	440	1.28	352	1.09	300
250	315	346	252	220	495	302	1.63	513	1.64	516	1.42	447	1.10	345
300	347	381	278	243	555	338	1.71	593	2.04	707	1.60	554	1.17	407
350	392	431	314	274	612	372	1.77	692	2.06	809	1.57	616	1.21	473
400	418	459	335	292	665	406	1.84	768	2.04	856	1.59	666	1.24	519
500	468	514	375	327	765	466	1.94	908	2.23	1004	1.74	815	1.26	589

Correction Factor for Room Temperature Over 30 C-86 F

Temp C	Temp F	
40	104	0.94
45	113	0.90
50	122	0.87
55	131	0.83
60	140	0.79
70	158	0.71
75	167	0.66
80	176	0.61

TABLE XVI

Typical Steel Plant Mill Motor Frame Lead Data

(This table lists the motor frame lead sizes designated by a typical steel plant electrical repair shop as replacements when motors are serviced. These sizes are based on the original manufacturers sizes modified by operating experiences and the sizes of cable normally stocked. Various ampere ratings are assigned for comparative purposes.)

Frame size	1 Hp ½-hr	2 Amp ½-hr	3 Hp 1-hr	4 Amp 1-hr	5 Lead size	6 Ampere carrying capacity from table XV Col. 1 code continuous	7 Col. 6 80 C ambient continuous	8 Col. 12 1-hr code modified	9 Col. 10 ½-hr code modified	10 Col. 14 code continuous modified
2	6½	29	5	21	6	80	72	93	105	85
3	10	44	7½	31	6	80	72	93	105	85
4	13½	57	10	40	6	80	72	93	105	85
6	19	77	15	57	4	107	96	126	147	113
8	33	126	25	95	2	137	128	163	190	148
10	45	175	35	132	1/0	190	175	239	294	209
12	65	245	50	185	2/0	217	202	275	331	243
14	100	368	75	272	4/0	275	272	352	440	300
16	135	500	100	360	4/0	275	272	352	440	300
18	200	740	150	540	500	468	466	815	1004	589
20	265	960	200	730	500	468	466	815	1004	589

TABLE XVII

Comparison of Motor Frame Lead Sizes

(This tabulation compares the manufacturer's and typical steel plants motor frame lead sizes and arbitrarily assigned current carrying capacities. Analysis of Tables XVI and XVII resulted in the selection of Column 3 lead sizes and Table XV, Column 6 carrying capacities as being representative for comparative purposes.)

Frame size	1 Hp ½-hr	2 Crocker-Wheeler		3 General Electric		4 Westinghouse		5 Typical steel plant	
		Size	Amp	Size	Amp	Size	Amp	Size	Amp
2	6½	6	72	6	72	12	31	6	72
3	10	6	72	6	72	12	31	6	72
4	13½	6	72	6	72	10	40	6	72
6	19	4	96	5	83	10	40	4	96
8	33	2	128	2	128	6	72	2	128
10	45	1	150	1	150	1	150	1/0	175
12	65	2/0	202	1/0	175	1	150	2/0	202
14	100	250	302	3/0	234	4/0	272	4/0	272
16	135	370	393*	250	302	4/0	272	4/0	272
18	200	2-250	604	400	406	4/0	272	500	466

*Estimated value.

TABLE XVIII

Comparison of Motor Current, Motor Frame Lead Data, and Conductor Cable Capacities

(Table XVIII compares motor frame lead sizes and capacities with various conductor cable sizes and ratings. Analysis of these data lead to the selection of the data shown in Table XIX, listing conductor cable sizes for series mill type motors, frame sizes 2 to 20.)

Frame size	1 Hp ½-hr	2 Amp ½-hr	3 Amp 1-hr	4 Frame lead size	5 Amp capacity continuous, Table XV, Col. 6	6 H&T capacity ½-hr rating equivalent to ½-hr motor amp Table IX		8 H&T capacity ½-hr rating equivalent to Col. 5 lead rating		10 H&T capacity 1-hr rating equivalent to 1-hr motor amp Table IX		12 H&T capacity 1-hr rating equivalent to Col. 5 lead rating		14 H&T capacity ½-hr rating equivalent to motor 1-hr amp	
						Size	Amp	Size	Amp	Size	Amp	Size	Amp	Size	Amp
2	6½	29	21	6	72	12	33	6	86	14	25	6	76	14	26
3	10	44	31	6	72	10	43	6	86	12	30	6	76	12	33
4	13½	57	40	6	72	8	60	6	86	10	40	6	76	10	40
6	19	77	57	5	83	6	86	6	86	8	60	5	85	8	60
8	33	126	95	2	128	3	141	3	141	4	100	2	137	5	95
10	45	175	132	1	150	1	175	2	160	2	137	1/0	190	3	141
12	65	245	185	1/0	175	2/0	267	1	175	1/0	190	1/0	190	1/0	233
14	100	368	272	3/0	234	4/0	369	1/0	233	3/0	280	3/0	280	3/0	341
16	135	500	360	250	302	300	582	3/0	302	250	364	250	364	4/0	369
18	200	740	540	400	406	500	847	250	420	400	538	300	455	300	582
20	265	960	730	650	605*	750	1020	350	646	700*	740	500	660	500	847

*Estimated value.

TABLE XIX

Conductor Sizes for Series Mill Type Motors, Frame Sizes 2 to 20

(This tabulation is a result of a study of Table XVIII data and is the basis for the proposed standards.)

Frame size	Heavy duty					Average duty				
	1 Hp ½-hr	2 Amp ½-hr	3 Condr size	4 Amp Table IX ½-hr 75 C	5 Amp Table XV Col. 10 110 C	6 Hp 1-hr	7 Amp 1-hr	8 Condr size	9 Amp Table IX 1-hr 75 C	10 Amp Table XV Col. 12 110 C
2	6½	29	8	60	80	5	21	8	55	73
3	10	44	8	60	80	7½	31	8	55	73
4	13½	57	8	60	80	10	40	8	55	73
6	19	77	6	86	105	15	57	6	76	93
8	33	126	2	160	190	25	95	4	100	126
10	45	175	1	175	215	35	132	2	137	163
12	65	245	2/0	267	331	50	185	1/0	190	239
14	100	368	4/0	369	440	75	272	3/0	280	339
16	135	500	300	582	707	100	360	250	364	447
18	200	740	500	847	1004	150	540	400	538	666
20	265	960	2-300	1164	1414	200	730	2-250	728	894

TABLE XX

Comparison of Conductor Cable Sizes

(This comparison tabulates frame lead, code, crane builders, steel plant, and proposed standard conductor sizes for mill type motors. As a matter of interest, the typical steel plant conductor sizes most closely approximate the proposed standard.)

Frame size	1 Hp ½ hr	2 Amp ½ hr	3 Hp 1 hr	4 Amp 1 hr	5 Frame lead size	6 Table XIX heavy duty RH-75 C	7 Table XIX average duty RH-75 C	8 1947 code ½- hr Table XIV Col. 1 R-60 C	8A 1947 code 1 hr Table XIV Col. 1 R-60 C
2	6½	29	5	21	6	8	8	10	12
3	10	44	7½	31	6	8	8	8	10
4	13½	57	10	40	6	8	8	6	8
6	19	77	15	57	5	6	8	4	6
8	33	126	25	95	2	2	4	1	2
10	45	175	35	132	1	1	2	2/0	1
12	65	245	50	185	1/0	2/0	1/0	3/0	2/0
14	100	368	75	272	3/0	4/0	3/0	300	4/0
16	135	500	100	360	250	300	250	400	300
18	200	740	150	540	400	500 2-250	350	2-300	450
20	250	960	200	730	650	2-300	500	2-400	2-300

various types and makes of crane type motors. See Tables XXI, XXII, and XXII-A and XXIII. Consideration is being given to the possibility of basing the standard on horsepower ranges, and one such proposal is outlined in Table XXII-A, which if adopted would replace Tables XXI and XXII.

The proposed standard conductor sizes have been based on consideration of the following:

1. The 1947 National Electrical Code short time ratings for crane and hoist service.
2. The Horstmann and Tousley short time conductor ratings for short time motor ratings.
3. Motor frame lead sizes used by motor manufacturers and by steel plant electrical shops.
4. Experiences of steel plant organizations in making new installations and replacements.
5. Preliminary test data.

Three conductor cable service classifications have been provided for the two classifications of crane service, to provide suitable size conductor standards as follows:

1. *Heavy duty*—Conductor cables in this class are based on current required for totally enclosed motors at their ½-hour rating and are capable of carrying this current for ½ hour.
2. *Average duty*—Conductor cables in this class are based on current required for totally enclosed motors at their 1-hour rating, and are capable of carrying this current for 1 hour. The use of the 1-hour current rating for this service is a convenient and uniform method of applying a 75 per cent load factor, based on the ratio of the 1-hour and ½-hour motor ratings. The load factor of 75 per cent is arbitrary, and is based on general considerations of cable sizes for small and large size motors, the effects of high current peaks on the cables when the motors are occasionally used for heavier-than-average service, and the possibility that type R or type T cable may be substituted for type RH cable because of misunderstandings of cable nomenclature, shortages of stock, etc.
3. *Heavy duty—force ventilated*—Conductor cables in this class are of suitable code continuous ratings, capable of carrying continuously the current required for totally enclosed force ventilated motors, worked at the 1-hour continuous rating. Such applications may be encountered on ore bridges, ore unloaders, etc., where force ventilation is utilized to obtain higher than normal ratings because of space limitations in applying larger size motors.

For each service class, there are listed the horsepower and ampere ratings for that service, the equivalent conductor cable sizes and ratings, and the size and number of conduits required.

In the interests of standardization and simplification, but two types of insulation are shown in the proposed standards, moisture resisting 75C type RH insulation with neoprene covering, and AVA 110C insulation with moisture resistant impregnation for high temperature service. For the same reasons, the conductor cable and conduit sizes specified for RH cable are specified for AVA insulation when AVA insulation is required because of high temperature conditions, although the increased capacity of the AVA insulation would permit smaller conduit sizes in some cases. Wire data are given in Table XXIII.

Also in the interests of standardization and simplification, a minimum size conductor cable is indicated, No. 8. Likewise, a maximum size conduit is indicated, 3 in. The limitation in conduit size also limits the maximum size conductor for this class of work to 500 MCM. In some cases this will require two conduits for each series motor circuit of four lines, and smaller size conductors may be paralleled to obtain the required carrying capacity.

For compound and shunt wound motor shunt field circuits, two No. 8 conductors in 1 in. conduit are specified. This isolates the shunt field circuit from the armature and series field circuits.

TEST DATA

A number of tests were conducted to investigate the results obtained under conditions similar to those set up for the tests made in 1918. A 400- amp d-c welding machine was used as a source of power instead of storage batteries. An indicating type potentiometer was

TABLE XX — Continued

Comparison of Conductor Cable Sizes

9	10	11	11A	12	13	14	15	16	17
1947 code continuous Table XIV Col. 2 R-60 C	1947 code continuous Table XIV Col. 3 RH-75 C	1947 code ½- hr 4-6 condrs Table XIV Col. 4 R-60 C	1947 code 1 hr Table XIV Col. 4 R-60 C	1947 code continuous 4-6 condrs Table XIV Col. 5 R-60 C	1947 code continuous 4-6 condrs Table XIV Col. 6 RH-75 C	Crane builders			Typical steel plant
						A	B	C	
10	10	8	8	8	8	10	6	12	8
6	8	6	8	6	6	8	6	10	8
5	6	4	6	4	5	6	6	10	6
3	4	2	4	2	3	4	4	8	6
1/0	1	1/0	1	3/0	2/0	2	1	6	4
4/0	2/0	3/0	2/0	250	4/0	1/0	2/0	4	1/0
300	250	250	3/0	500	350	3/0	4/0	2	2/0
2-4/0	500	350	250	2-300	2-4/0	2-2/0	400	1/0	4/0
2-350	2-250	500	350	2-500	2-350	2-3/0	2-4/0	2/0	350
3-350	2-500	2-350	2-250	3-500	3-350	3-3/0	.....	.....	500
3-500	3-400	2-500	2-350	4-500	4-350	.....	.....	.....	2-300

TABLE XXI

AISE Wiring Standards—AISE D-C Mill Motor

Motor frame data					Motor frame ratings						Average intermittent duty service		Heavy intermittent duty service		Continuous duty force ventilated service	
AISE 1949	AISE 1940	General Electric	Westing-house	Crocker Wheeler	Hp 1 hr	Amp 1 hr	Hp ½ hr	Amp ½ hr	Hp cont	Amp cont	Condr size per leg	Conduit size, in.	Condr size per leg	Conduit size, in.	Condr size per leg	Conduit size, in.
2	2	MD-402	MC-21	SW-5	5	21	6½	29	5	21	8	1¼	8	1¼	8	1¼
602	3	MD-403	MC-31	SW-7½	7½	31	10	44	7½	31	8	1¼	8	1¼	8	1¼
603	4	MD-404	MC-41	SW-10	10	40	13½	57	10	40	8	1¼	8	1¼	8	1¼
604	6	MD-406	MC-61	SW-15	15	57	19	77	15	57	8	1¼	6	1¼	6	1¼
606	8	MD-408	MC-81	SW-25	25	95	33	126	25	95	4	1½	2	2	2	2
608	10	MD-410	MC-101	SW-35	35	132	45	175	35	132	2	2	1	2	1/0	2
610	12	MD-412	MC-121	SW-50	50	185	65	245	50	185	1/0	2	2/0	2½	3/0	2½
612	14	MD-414	MC-141	SW-75	75	272	100	368	75	272	3/0	2½	4/0	2½	300	3
614	16	MD-416	MC-161	SW-100	100	360	135	500	100	360	250	3	300	3	500	3(2)*
															2-3/0	2½(2)
616	18	MD-418	MC-181	SW-150	150	540	200	740	150	540	400	3(2)*	500	3(2)*		
											2-3/0	2½(2)	2-250	3(2)	2-300	3(2)
618	.....	MD-420	.....	.....	200	730	265	960	200	730	2-250	3(2)	2-300	3(2)	2-500	3(4)

*Numbers in parentheses indicate number of conductors in conduit.

Figure 1 — This is a reproduction of the time-temperature curve developed for three No. 4/0 conductors during tests made by Horstmann and Tousley in 1918.

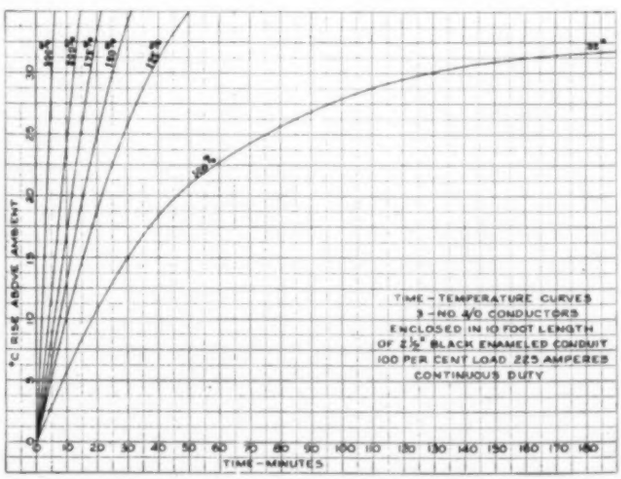


Figure 2 — Result of the first test made in 1949 to investigate the method used in 1918. This test was made on three 1/0 conductors.

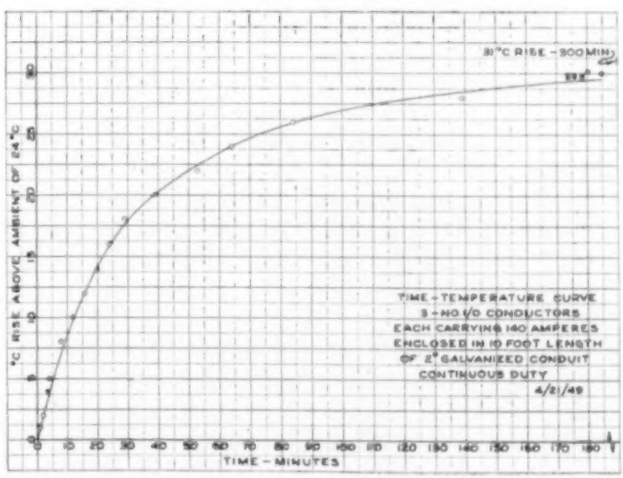


TABLE XXII

AISE Wiring Standards—Miscellaneous D-C Motors

Motor data								Average intermittent duty service		Heavy intermittent duty service		Continuous duty force ventilated service	
Frame size	Mfr	Hp 1 hr	Amp 1 hr	Hp ½ hr	Amp ½ hr	Hp cont	Amp cont	Condr size per leg	Conduit size, in.	Condr size per leg	Conduit size, in.	Condr size per leg	Conduit size, in.
101	G-E	4	17	5	23	4	17	8	1¼	8	1¼	8	1¼
20	West	6	25	7½	34	6	25	8	1¼	8	1¼	8	1¼
AW	C-W	8	37	10	50	8	37	8	1¼	8	1¼	8	1¼
102	G-E	9	33	12	50	9	33	8	1¼	8	1¼	8	1¼
30	West	12	47	15	62	12	47	8	1¼	6	1¼	6	1¼
103	G-E	13	50	17	70	13	50	8	1¼	6	1¼	6	1¼
BW	C-W	16	56	20	86	16	56	8	1¼	6	1¼	6	1¼
40	West	20	76	28	116	20	76	6	1¼	4	1½	4	1½
104	G-E	20	77	30	124	20	77	6	1¼	2	2	4	1½
CW	C-W	25	88	30	112	25	88	6	1¼	4	1½	2	2
104½	G-E	30	112	45	175	30	112	3	1½	1	2	2	2
50	West	30	114	40	157	30	114	3	1½	2	2	2	2
DW	C-W	36	138	45	180	36	138	2	2	1	2	1/0	2
105	G-E	40	154	50	200	40	154	1	2	1/0	2	1/0	2½
EW	C-W	47	175	60	245	47	175	1/0	2	2/0	2½	2/0	2½
60	West	50	172	65	250	50	172	1/0	2	2/0	2½	2/0	2½
FW	C-W	66	240	85	320	66	240	3/0	2½	3/0	2½	250	3
70	West	70	255	90	346	70	255	3/0	2½	4/0	2½	250	3
106	G-E	70	264	85	324	70	264	3/0	2½	4/0	2½	300	3
107	G-E	85	316	110	432	85	316	4/0	2½	250	3	350 2-2/0	3(2)* 2½(2)
80	West	85	320	110	410	85	320	4/0	2½	250	3	350 2-2/0	3 2½(2)
GW	C-W	90	310	110	400	90	310	4/0	2½	250	3	350	3(2)
90	West	100	360	140	520	100	360	250	3	300	3	500 2-3/0	3(2) 2½(2)
108	G-E	100	365	140	565	100	365	250	3	300	3	500 2-3/0	3 2½(2)
HW	C-W	120	440	160	590	120	440	300	3	350	3(2)*	2-4/0	2½(2)
100	West	150	540	200	730	150	540	400 2-3/0	3(2)* 2½(2)	500 2-250	3(2) 3(2)	2-300	3(2)
IW	C-W	175	620	225	800	175	620	500 2-4/0	3(2) 2½(2)	2-250	3(2)	2-350	3(4)
109	G-E	175	640	225	840	175	640	500	3(2)	2-250	3(2)	2-350	3(2)
103	West	180	660	250	900	180	660	2-250	3(2)	2-300	3(2)	2-400	3(4)
165	West	275	970	325	1160	275	970	2-350	3(2)	2-400	3(2)	3-400	3(4)

*Numbers in parentheses indicate number of conductors in conduit.

used for the first two tests. All subsequent tests were made with a direct reading curve drawing potentiometer to record the temperature changes.

Tests were made on three conductors and the results compared with the data given by Horstmann and Tousley. Tests were then made on four conductors and the results compared with the data obtained for three conductors.

Figure 1 shows the curve developed in 1918 for three 4/0 conductors carrying code rated current of 225 amp.

Figure 2 shows the curve developed in 1949 for three 1/0 conductors carrying 140 amp continuously. According to Table VII, 143 amp should give a temperature rise of 30C. Substituting in the formula $I = \sqrt{KC}$, $140 = \sqrt{684 \times C}$, the temperature rise should approximate 28.7C and should require about 238 minutes. Figure 2 indicates a temperature rise of 31C in 300 minutes. However, the ambient temperature at the conclusion of the test was about 4C higher than when the test began. If the temperature rise of 33.6C at 238 minutes is decreased by the 4C differential, the equivalent temperature rise becomes 29.6C. This is in good agreement with the Horstmann and Tousley data, and the curve obtained follows the pattern shown in Figure 1.

Figure 3 gives the results of a similar test made with four 1/0 conductors. A temperature rise of 31C in 143 minutes is indicated. The ambient temperature differential during this test was only 1C.

Figure 4 indicates the results of three 1/0 conductors carrying 165 amperes continuously. According to Table VII, and calculations, the temperature rise for this condition should be 40C, in 170 minutes. The figure gives a temperature rise of 38C in 170 minutes. The code continuous rating for three type RH conductors is 150 amp.

Figure 4A reproduces the curve drawing chart of the

TABLE XXII-A

ALTERNATE TABLE FOR TABLES XXI AND XXII

Wire Sizes for D-c Mill Type Motors

Motor frame data						Heavy duty intermittent service		Average duty intermittent service		Heavy duty continuous force ventilated service	
Hp ½ hour	Amp ½ hour	Hp 1 hour	Amp 1 hour	Hp continuous force ventilated	Amp continuous force ventilated	Conductor size per leg	Conduit number and size, in.	Conductor size per leg	Conduit number and size, in.	Conductor size per leg	Conduit number and size, in.
5-13½	23-57	4-10	17-40	4-10	17-40	8	1-1¼	8	1-1¼	8	1-1¼
15-20	62-86	12-16	47-57	12-16	47-57	6	1-1¼	8	1-1¼	6	1-1¼
28-40	116-157	20-30	76-114	20-30	76-114	2	1-2	4	1-1½	2	1-2
45	175-180	30-36	112-138	30-35	112-138	1	1-2	2	1-2	1	1-2
50	200	40	154	40	154	1/0	1-2	1	1-2	1/0	1-2
60-65	245-250	47-50	175-185	47-50	175-185	2/0	1-2½	1/0	1-2	3/0	1-2½
85-100	320-368	66-75	240-272	66-75	240-272	4/0	1-2½	3/0	1-2½	300	1-3
110	400-432	85-90	310-320	85-90	310-320	250	1-3	4/0	1-2½	350 or 2-2/0	2-3 2-2½
135-140	500-565	100	360-365	100	365	300	1-3	250	1-3	500 or 2-3/0	2-3 2-2½
160	590	120	440	120	440	350	2-3	300	1-3	2-4/0	2-2½
200-225	730-840	150-175	540-640	150-175	540-640	2-250	2-3	500	2-3	2-350	4-3
250-265	900-960	180-200	660-730	180-200	660-730	2-300	4-3	2-250	2-3	2-500	4-3
325	1160	275	970	275	970	2-400	4-3	2-350	4-3	3-400	4-3

test data for Figure 4. In addition to the 165 amp continuous run, an intermittent test was made for 200 amp, 154 sec on (51.4 per cent) and 144 seconds off. The temperature rise for this test was 32.2C. This figure illustrates the improvement in data provided for the curves subsequent to Figure 3.

Figure 5 shows the results when four 1/0 conductors carry 165 amp continuously. The temperature rise is 40.9C in 151 minutes. The slight increase in temperature rise from 151 minutes to 190 minutes is attributed to an increase of 4C in the ambient temperature while the test was in progress. Applying the code factor of 0.8 for 4-6 conductors, the code continuous rating for four 1/0 conductors would be 120 amp.

Figure 6 gives the effect of an intermittent duty cycle of 96 seconds on (32 per cent) and 204 seconds off, when three 1/0 conductors carry 200 amp. The maximum temperature rise is 20.6C reached in 157 minutes. The increase in temperature beyond 157 minutes is again due to an increase in the ambient temperature. It will be observed that the characteristic of the curve for this type test is a "saw-tooth." This duty cycle

TABLE XXIII

Wire Data

Wire size	RH 75C Wire—Amp			AVA 110C Wire—Amp			RH 75C Wire	
AWG and MCM	60 min rating	30 min rating	Continuous rating	60 min rating	30 min rating	Continuous rating	Insulation thickness, in.	Jacket thickness, in.
8	55	60	45	73	80	60	4/64	1/64
6	76	86	65	93	105	80	4/64	2/64
4	100	117	85	126	147	107	4/64	2/64
2	137	160	115	163	190	137	4/64	2/64
1	143	175	.....	177	215	161	5/64	3/64
1/0	190	233	150	239	294	190	5/64	3/64
2/0	222	267	175	275	331	217	5/64	3/64
3/0	280	341	200	339	413	243	5/64	3/64
4/0	295	369	230	352	440	275	5/64	3/64
250	364	420	255	447	516	315	6/64	4/64
300	455	582	285	554	707	347	6/64	4/64
350	486	646	310	616	809	392	6/64	4/64
400	538	688	335	666	856	418	6/64	4/64
500	660	847	380	815	1004	468	6/64	4/64

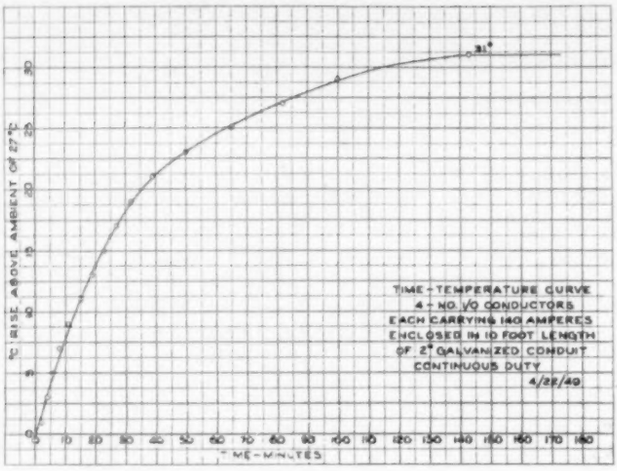


Figure 3 — This is similar to Figure 2 and shows the results of tests on four 1/0 conductors. These first two tests were made with an indicating type potentiometer. Both Figure 2 and Figure 3 follow the pattern of the curve in Figure 1. Temperature rise is 31 C.

approximates the 50-hp rating of an MDP-105 mill type motor.

Figure 7 shows the 200-amp, 32 per cent duty cycle applied to four 1/0 conductors. The temperature rise in 137 minutes is 25C, and in 157 minutes is 25.5C compared with 20.6 for three 1/0 conductors. The increase in temperature rise beyond 137 minutes is attributed to the increase in ambient. The temperature rise of 25.5C indicates that the four 1/0 conductors are conservatively rated for the MDP-105 mill motor 32 per cent duty cycle. As a matter of fact, the 32 per cent, 200-amp duty is rather high for the MDP-105 motor, for the characteristic curve shows that 180 amp is the maximum load for 32 per cent on duty.

Figure 8 gives the temperature rises when three 1/0 conductors carry 227 amp for ½ hour, approximating the Table IX rating of 233 amp, and 190 amp for 1 hour which is the Table IX rating. The temperature rise is 36.7C for the 227-amp load and 37.8C for the 190-amp load.

Figure 9 indicates the results when four 1/0 conductors carry loads similar to those of Figure 8. The current for the ½-hour rating test is 230 amp approximating the 233 amp of Table IX, and the current for the 1-hour rating test is 187 amp approximating the 190 amp of Table IX. The temperature rises of 40.6C and 39.4C respectively, compare with the 36.7C and 37.8C for the loads in Figure 8 for three 1/0 conductors.

Figure 10 shows a 200-amp, 50 per cent duty cycle for four 1/0 conductors producing a rise of 35.5C. This duty cycle exceeds the 50-hp intermittent rating of an MDP-105 mill motor for which Figure 7 gives a rise of 26.5C.

Figure 11 indicates a rise of 31.25C when three 1/0 conductors carry 165 amperes continuously in a 2½ in. conduit. This compares with a rise of 38C in Figure 4 for three 1/0 conductors in a 2 in. conduit. The increase in conduit size results in a decrease in temperature rise.

Figure 12 gives a rise of 21C for four No. 4 conductors carrying 125 amperes for an intermittent duty cycle of 39 seconds on (13 per cent) and 261 seconds off. This duty approximates the 45-hp intermittent rating

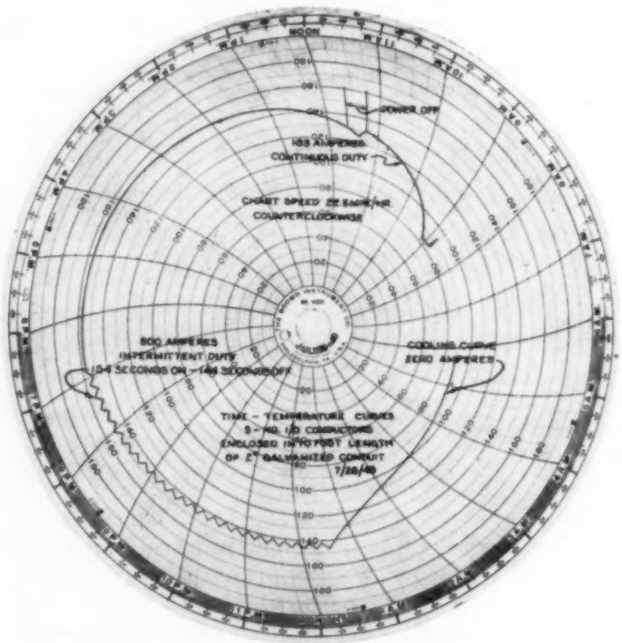
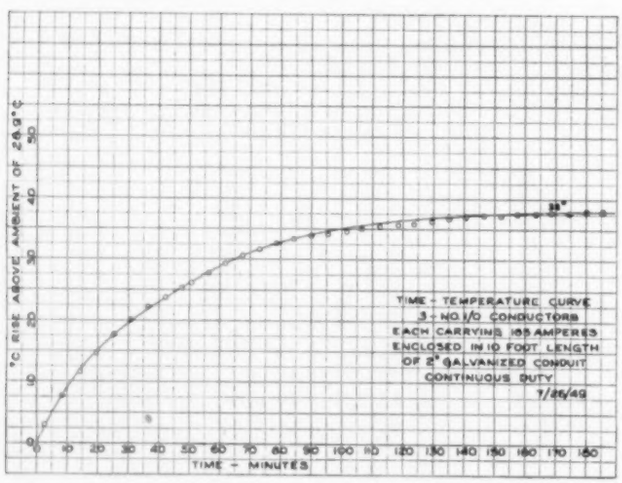


Figure 4a — The circular chart provides the data for Figure 4. In addition to the continuous duty test, an intermittent test run of 200 amp, 154 sec on (51.4 per cent) and 144 sec off, indicates a temperature rise of 32.2 C.

Figure 4 — This curve indicates a temperature rise of 38 C, when three 1/0 conductors carry 165 amp continuously. The code continuous rating for three type RH conductors (75 C rise) is 150 amp.



of an MD-410 enclosed mill motor. The No. 4 conductor is specified by crane builder "C" for this size motor.

Figure 13 shows the effects of applying the 175-amp (½-hour rating) to four No. 4 conductors continuously. The temperature rise is 65.5C in 19 minutes. Figures 12 and 13 show why a given conductor size may be satisfactory for light duty and average duty service and fail in heavy duty service.

Figure 14 presents the results of three 2/0 conductors carrying 200 amperes continuously for 130 minutes. The temperature rise is 41.5C.

Figure 15 discloses that four 2/0 conductors carrying 202 amperes continuously for 130 minutes will develop a temperature rise of 54C. This indicates that the 200 ampere continuous rating as shown in Table IX for

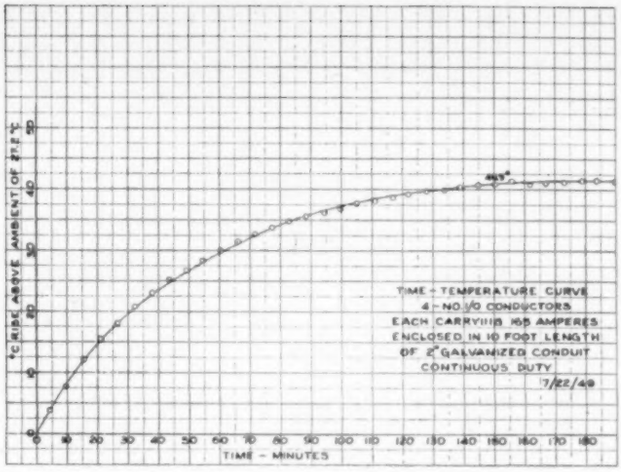


Figure 5 — A temperature rise of 40.9 C was developed in 151 minutes when four 1/0 conductors carry 165 amp continuously. The ambient temperature increased 4 C during the progress of this test. Applying the code factor of 0.8 for 4-6 conductors, the code continuous rating would be 150 x 0.8 or 120 amp.

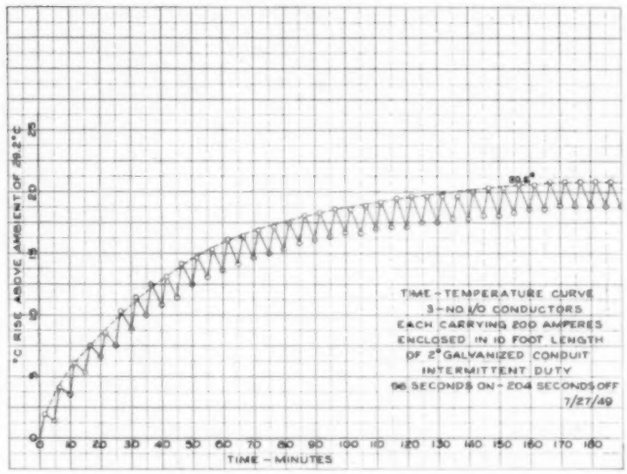
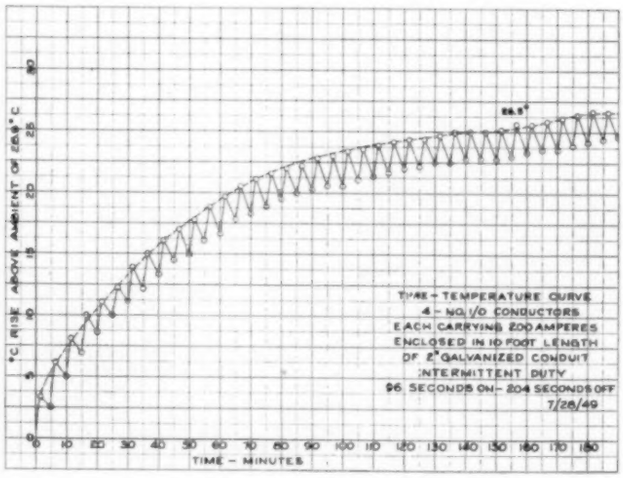

TIME - TEMPERATURE CURVE
3 - NO 1/0 CONDUCTORS
EACH CARRYING 200 AMPERES
ENCLOSED IN 10 FOOT LENGTH
OF 2" GALVANIZED CONDUIT
INTERMITTENT DUTY
96 SECONDS ON - 204 SECONDS OFF
7/27/49
°C RISE ABOVE AMBIENT OF 29.2 °C
TIME - MINUTES

Figure 6 — Time-temperature curve for three 1/0 conductors carrying 200 amp for an intermittent duty cycle of 96 sec on (32 per cent) and 204 sec off. The temperature rise is approximately 20.6 C in 157 min.

Figure 7 — This shows that the 200-amp, 32 per cent time on duty cycle for four 1/0 conductors gives a rise of 26.5 C. This duty approximates the 50-hp intermittent rating of an MDP-105 mill motor.


TIME - TEMPERATURE CURVE
4 - NO 1/0 CONDUCTORS
EACH CARRYING 200 AMPERES
ENCLOSED IN 10 FOOT LENGTH
OF 2" GALVANIZED CONDUIT
INTERMITTENT DUTY
96 SECONDS ON - 204 SECONDS OFF
7/28/49
°C RISE ABOVE AMBIENT OF 29.6 °C
TIME - MINUTES

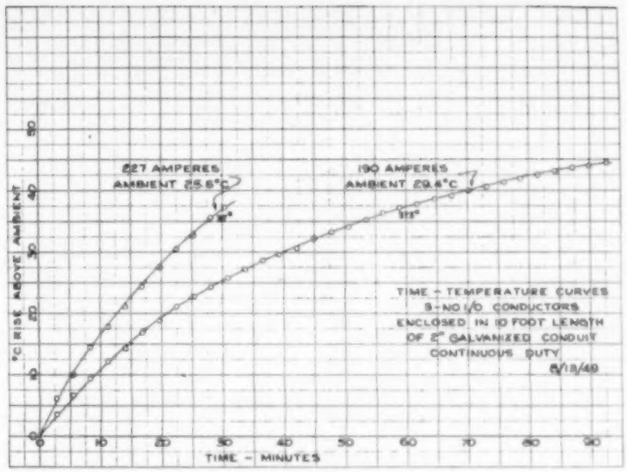


Figure 8 — Temperature rise for three 1/0 conductors when carrying 227 amp for 30 min and 190 amp for 60 min, approximating the ratings shown in Table IX.

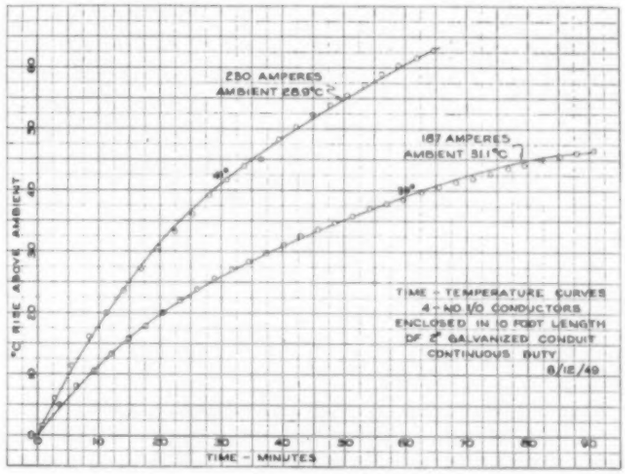
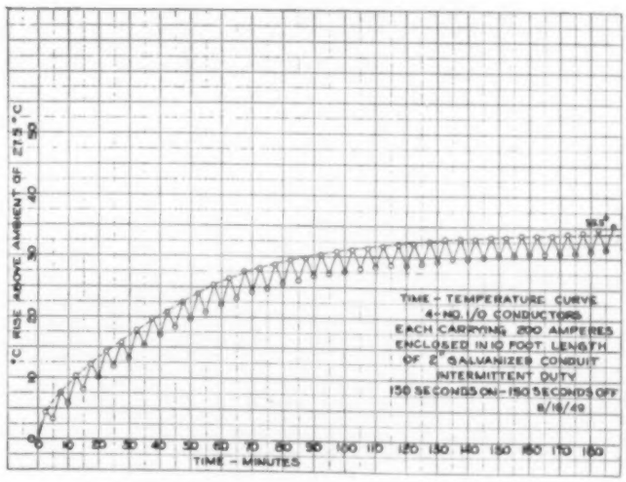


Figure 9 — Temperature rise for four 1/0 conductors when carrying 230 amp for 30 min and 187 amp for 60 min approximating the ratings shown in Table IX.

Figure 10 — A 200-amp, 50 per cent time on duty cycle for four 1/0 conductors produces a rise of 35.5 C. This duty cycle exceeds the 50-hp intermittent rating of an MDP-105 mill motor for which Figure 7 gives a rise of 26.5 C.


TIME - TEMPERATURE CURVE
4 - NO 1/0 CONDUCTORS
EACH CARRYING 200 AMPERES
ENCLOSED IN 10 FOOT LENGTH
OF 2" GALVANIZED CONDUIT
INTERMITTENT DUTY
150 SECONDS ON - 150 SECONDS OFF
8/16/49
°C RISE ABOVE AMBIENT OF 27.5 °C
TIME - MINUTES

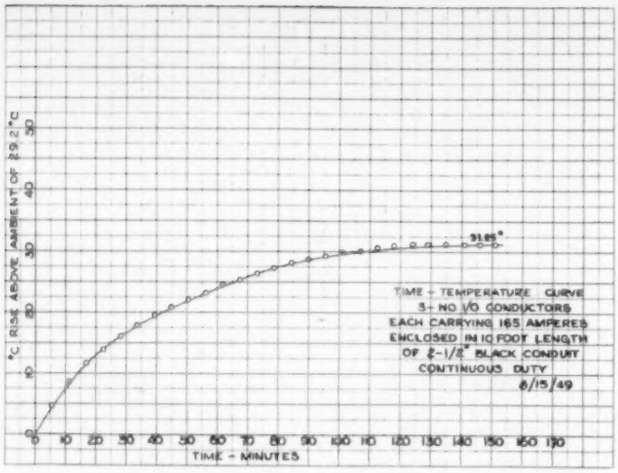


Figure 11 — A rise of 31.25 C is indicated when three 1/0 conductors carry 165 amp continuously in a 2½-in. conduit. This compares with a rise of 38 C in Figure 4 for three 1/0 conductors in a 2-in. conduit.

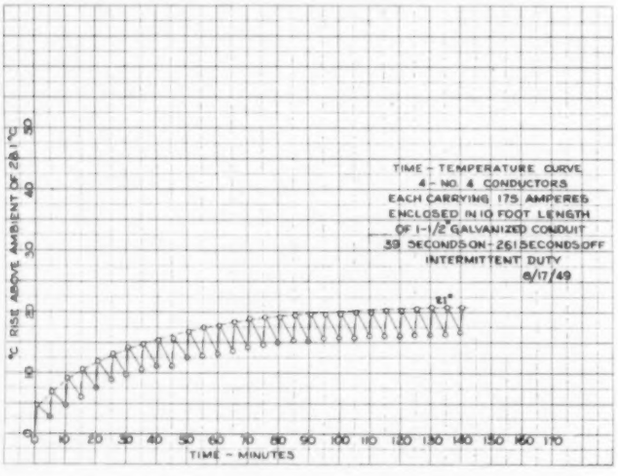
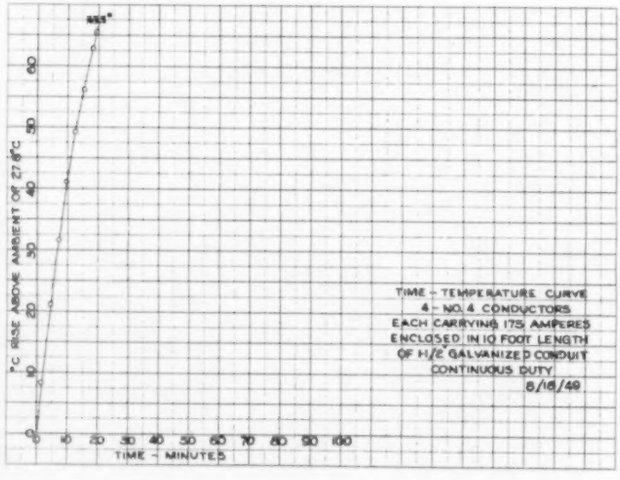

°C RISE ABOVE AMBIENT OF 28.1°C
TIME - MINUTES
TIME - TEMPERATURE CURVE
4 - NO. 4 CONDUCTORS
EACH CARRYING 175 AMPERES
ENCLOSED IN 10 FOOT LENGTH
OF 1-1/2" GALVANIZED CONDUIT
39 SECONDS ON - 261 SECONDS OFF
INTERMITTENT DUTY
8/17/49

Figure 12 — A rise of 21 C was obtained for four No. 4 conductors carrying 175 amp for an intermittent duty cycle of 39 sec on (13 per cent) and 261 sec off. This duty approximates the 45-hp intermittent rating of an MD 410 mill motor. The No. 4 conductor is specified by crane builder "C" for this size motor.

Figure 13 — Effect of applying the 175-amp, ½-hr rating to four No. 4 conductors. The rise is 65.5 C in 19 minutes. Figures 12 and 13 show why a given conductor size may be satisfactory for average duty service and fail in heavy duty service.



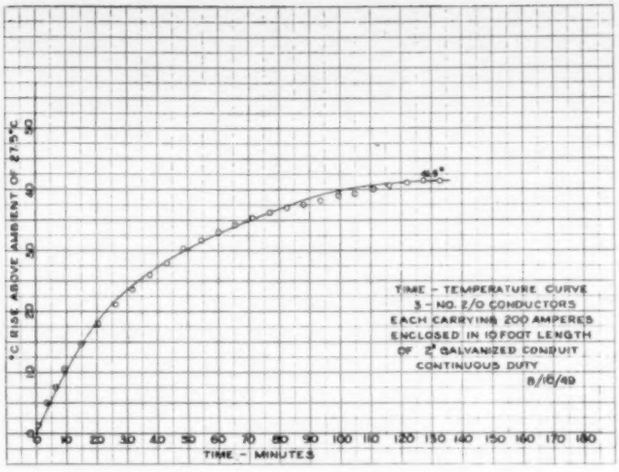


Figure 14 — Results of three 2/0 conductors carrying 200 amp continuously for 130 min. The temperature rise is 41.5 C.

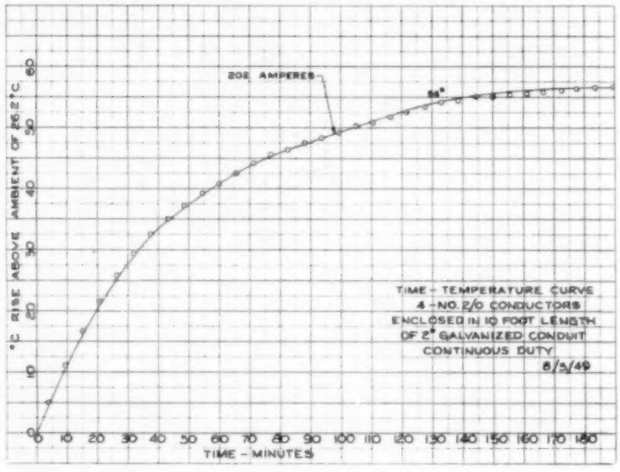
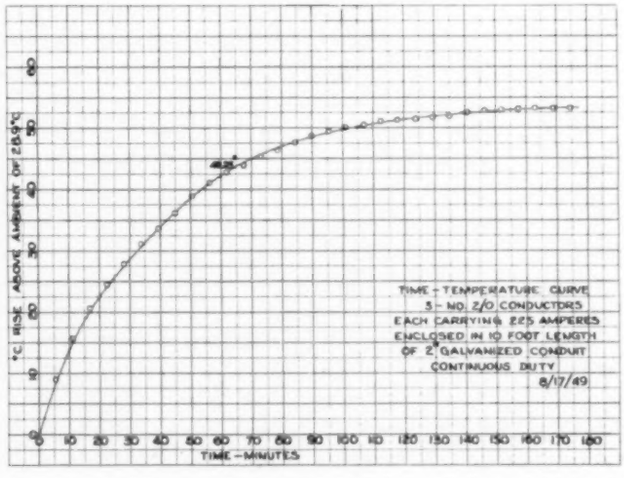


Figure 15 — Four 2/0 conductors carrying 202 amp continuously for 130 minutes will give a temperature rise of 54 C. This indicates that a 200-amp continuous rating is excessive for four conductors in conduit.

Figure 16 — Three 2/0 conductors carrying 225 amp show a temperature rise of 42.25 C in 60 min.



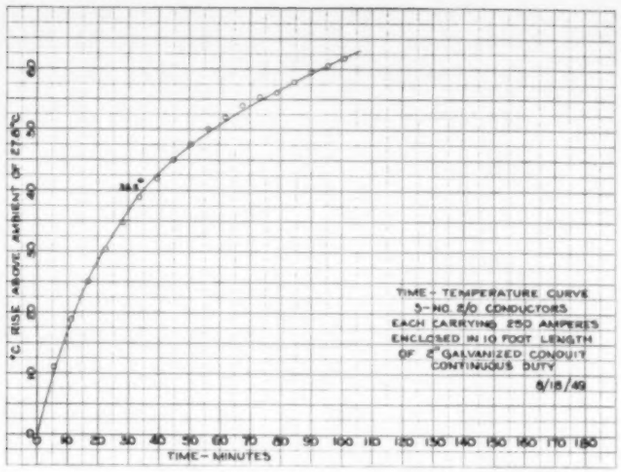


Figure 17 — Three 2/0 conductors carrying 250 amp show a temperature rise of 36.5 C in 30 min.

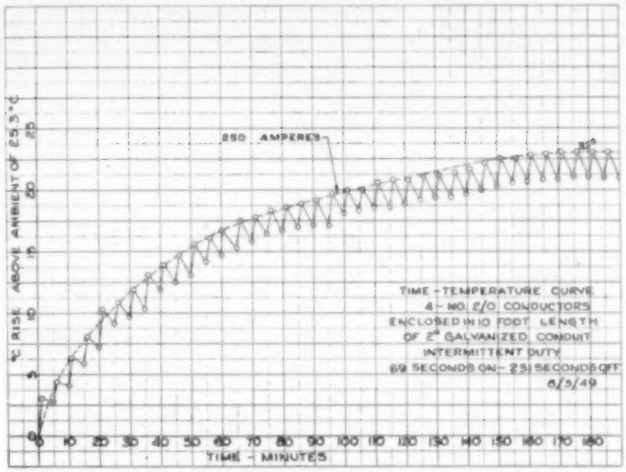


Figure 20 — A temperature rise of but 23 C is developed when four 2/0 conductors carry 250 amp for a duty cycle of 69 sec on (23 per cent) and 231 sec off. This duty cycle approximates the 23 per cent duty cycle of enclosed frames 610 or No. 12 for 65 hp.

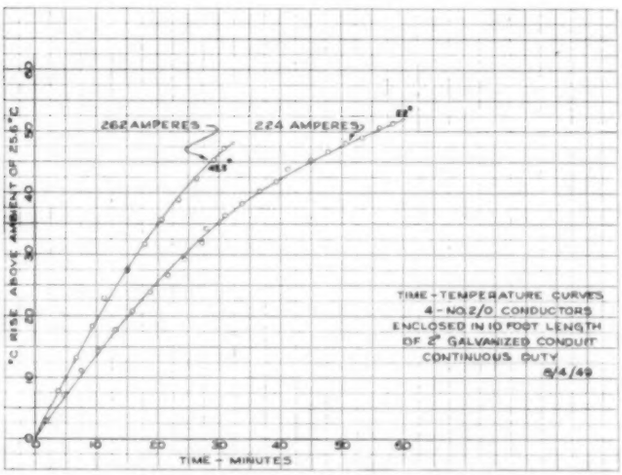


Figure 18 — Four 2/0 conductors carrying the Table IX, thirty and sixty minute ratings will have temperature rises in excess of 40 C.

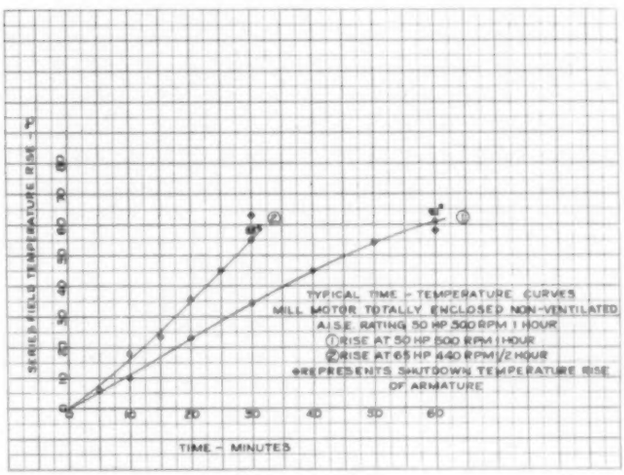
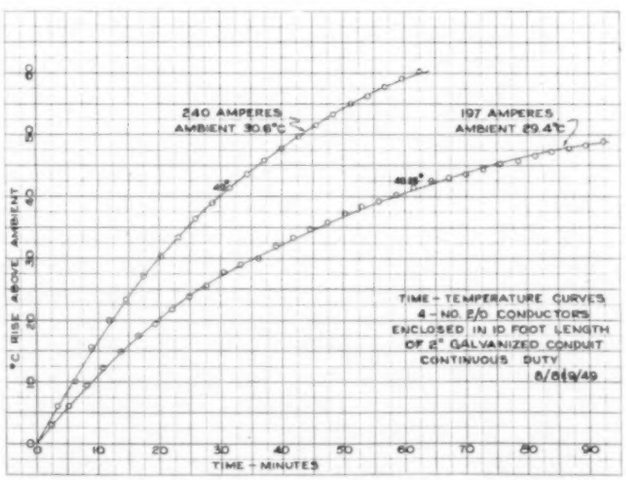
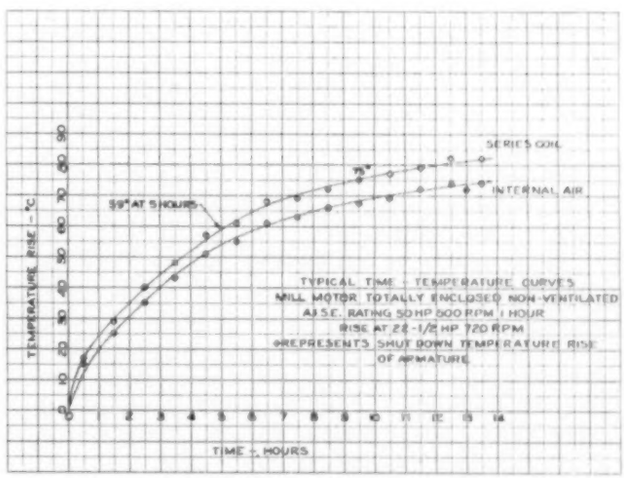

SERIES FIELD TEMPERATURE RISE - °C
TIME - MINUTES
TYPICAL TIME - TEMPERATURE CURVES
MILL MOTOR TOTALLY ENCLOSED NON-VENTILATED
A.I.S.E. RATING 50 HP 500 RPM 1 HOUR
① RISE AT 50 HP 500 RPM 1 HOUR
② RISE AT 65 HP 440 RPM 1/2 HOUR
● REPRESENTS SHUTDOWN TEMPERATURE RISE
OF ARMATURE

Figure 21 — Typical time-temperature curves for an AISE standardized mill motor operating at rated load of 50 hp for 1 hr, and 65 hp for ½ hr.

Figure 19 — Four 2/0 conductors carrying reduced current values of 240 and 197 amp for the 30-minute and 60-minute ratings respectively will have temperature rises closely approximating 40 C.

Figure 22 — Typical time-temperature curves for the same motor shown in Figure 21 running at rated load for continuous operation.




TEMPERATURE RISE - °C
SERIES COIL
INTERNAL AIR
59° AT 5 HOURS
TIME - HOURS
TYPICAL TIME - TEMPERATURE CURVES
MILL MOTOR TOTALLY ENCLOSED NON-VENTILATED
A.I.S.E. RATING 50 HP 500 RPM 1 HOUR
RISE AT 22-1/2 HP 720 RPM
● REPRESENTS SHUT DOWN TEMPERATURE RISE
OF ARMATURE

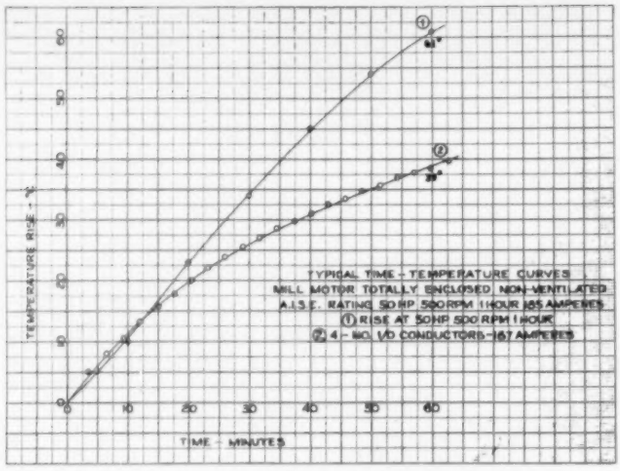

TYPICAL TIME - TEMPERATURE CURVES
MILL MOTOR TOTALLY ENCLOSED NON-VENTILATED
A.I.S.E. RATING 50 HP 500 RPM 1 HOUR 185 AMPERES
① RISE AT 50 HP 500 RPM 1 HOUR
② 4 - NO. 1/0 CONDUCTORS - 187 AMPERES
TEMPERATURE RISE - °C
TIME - MINUTES

Figure 23 — Comparison of time-temperature curves for an AISE standardized mill motor running at 50-hp rated load of 185 amp for 1 hr, and four 1/0 conductors in conduit carrying 187 amp.

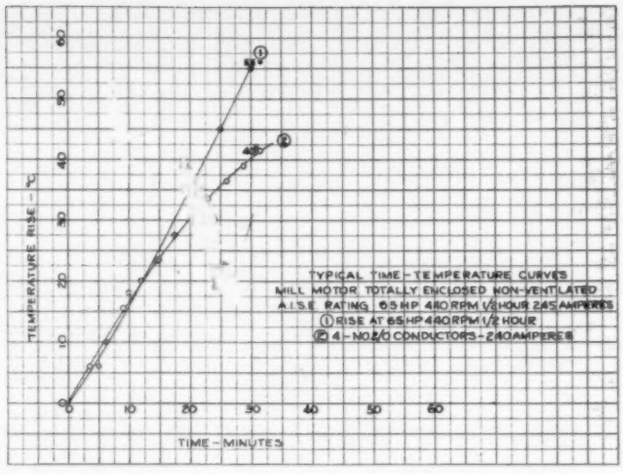

TYPICAL TIME - TEMPERATURE CURVES
MILL MOTOR TOTALLY ENCLOSED NON-VENTILATED
A.I.S.E. RATING 65 HP 480 RPM 1/2 HOUR 245 AMPERES
① RISE AT 65 HP 480 RPM 1/2 HOUR
② 4 - NO. 2/0 CONDUCTORS - 240 AMPERES
TEMPERATURE RISE - °C
TIME - MINUTES

Figure 24 — Comparison of time-temperature curves for an AISE standardized mill motor running at 65-hp rated load of 245 amp, and four 2/0 conductors carrying 240 amp.

three conductors in conduit is too high for four conductors.

Figure 16 for three 2/0 conductors carrying 225 amperes shows a temperature rise of 42.25C in 60 minutes.

Figure 17 for three 2/0 conductors carrying 250 amperes shows a temperature rise of 36.5C in 30 minutes.

Figure 18 discloses that four 2/0 conductors carrying the Table IX thirty and sixty minute ratings of 262 and 224 amperes respectively, will have temperature rises which appreciably exceeds 40C.

Figure 19 indicates that four 2/0 conductors carrying reduced current values of 240 and 197 for the thirty minute and sixty minute ratings respectively, will have temperature rises closely approximating 40C. These reduced values were calculated using the formulas given previously and the data obtained in Figure 19.

Figure 20 develops a temperature rise of but 23C when four 2/0 conductors carry 250 amperes for a duty cycle of 69 seconds on (23 per cent) and 231 seconds off. This duty cycle approximates the 23 per cent duty cycle of frames 610 and No. 12 for 65-hp.

CONCLUSIONS

1. As indicated by typical comparative conductor cable tabulations, there are considerable differences in the methods used by equipment suppliers and users in selecting conductor cables for mill type motors for overhead travelling crane service. This emphasizes the need for a uniform method of selecting conductor cables.

2. Although some work has been done in setting up short time conductor ratings comparable with short time motor ratings, such work is little known and is not generally recognized.

The Horstmann and Tousley ratings (Table IX), if proven satisfactory, would appear to provide a uniform basis for selecting conductors for mill and crane service.

3. Preliminary tests appear to substantiate the methods developed by Horstmann & Tousley in determining the ½-hour, 1-hour, and continuous ratings for three conductors in conduit, for a 40C temperature rise. Such ratings are more favorable than the 1947 code continuous and the ½-hour-1-hour crane and hoist ratings based on a 30C temperature rise.

4. Preliminary tests indicate that four conductors installed in the same size conduit as three conductors does not increase the temperature rise in the same proportion as the increase in the number of conductors. The code specification for an 8/10 rating multiplier for the range of 4 to 6 conductors in conduit appears to be more conservative than is necessary for four conductors.

5. Preliminary tests indicate that conductor intermittent duty cycles, based on intermittent motor ratings, give less temperature rise than ½-hour and 1-hour duty cycles for a given frame size.

6. Additional test work is desirable to determine the behavior of four conductors with varying size conduits and load conditions equivalent to continuous, 1-hour, and ½-hour ratings.

7. The Horstmann and Tousley half hour conductor ratings range from 109 per cent (for No. 14) to 173 per cent (for 500 MCM) of their continuous ratings, with an overall average of 136 per cent. This compares with an average of 260 per cent for similarly rated mill type motors. Their one hour conductor ratings range from 104 per cent (for No. 14) to 134 per cent (for 500 MCM) of their continuous ratings, with an overall average of 114 per cent. This compares with an average of 190 per cent for similarly rated mill type motors.

8. Selection of code continuous rated conductors based on short time motor current ratings results in larger conduit and conductor cable systems than are necessary to obtain safe satisfactory performance. This is particularly true of the larger size motor applications.

9. Selections of code continuous rated conductors based on continuous motor current ratings result in unsafe and unsatisfactory conduit and conductor cable systems if the motors are actually used for equivalent one-half of one hour duty cycles. Such systems will require early replacement. The replacement of such systems under adverse operating conditions is an expensive and time consuming procedure.

10. The recent AISE standardization of the one hour

rating for mill type motors also emphasizes the necessity for a uniform method of selecting conductor cables.

In the proposed standards now being submitted by the crane wiring committee for consideration, the frame size, ½-hour horsepower, ½-hour current, 1-hour horsepower, and 1-hour current relations are all maintained to assist in properly selecting conductor cable sizes.

DISCUSSION

PRESENTED BY

H. H. ANGEL, Electrical Engineer, Construction and Engineering Dept., Bethlehem Steel Co., Bethlehem, Pa.

FRANK CRAMER, Consulting Engineer, Elliott Co., Pittsburgh, Pa.

W. P. LEWIS, District Engineer, American Steel & Wire Co., Pittsburgh, Pa.

MARC DE FERRANTI, Manager, Materials Handling Division, General Electric Co., Schenectady, N. Y.

C. B. HATHAWAY, Manager, D-C Motor Engineering Dept., Westinghouse Electric Corp., Buffalo, N. Y.

J. N. HARTZELL, JR., Morgan Engineering Co., Alliance, Ohio

BOHDAN YAGELLO, Electrical Engineer, Alliance Machine Co., Alliance, Ohio.

J. D. O'ROARK, Electrical Supt., Weirton Steel Co., Weirton, W. Va.

C. G. DIMITT, Co-Chairman, AISE Crane Wiring Committee.

H. H. Angel: Mr. Dimitt is to be complimented on the fine paper he has presented; a lot of work has been done in bringing the data to our attention. There is every indication that the proposed sizes are a result of a real engineering study and not, as has been indicated in one of his remarks, on the whim of someone just stating, "Well, we will use size two for a certain motor," and not check it engineering-wise to determine whether it is correct.

From my experience I do not think there has been too much trouble encountered in overheating of crane wiring motor cables. There might be some where a few motors, probably on bridges, have required the use of blowers to reduce heating. I know of several cases where the motors used on mill tables and screwdowns were badly overloaded and eventually larger size cables have been installed.

A number of plants do not carry all sizes of wire in the storehouses. For example, in one of our Bethlehem Steel Company plants, sizes No. 3 and 3/0 are not carried; in another plant size 250,000 circular mill is not carried, but size 4/0, which is about 211,000 circular mills, and size 300,000 circular mills are carried.

I believe that in general the same size conduit wiring for motor leads is installed whether for crane or mill service. I know of several cases where the leads coming out of the motors have been small because when applied to heavy service, these leads which were attached to and were adjacent to other field coils were roasted and caused the motor failure.

Table XXIV shows the first seven columns and No. 17 column of Table XX in Mr. Dimitt's paper, plus the addition of columns 5A and 5B which represent the sizes taken from some tabulations obtained from the Lackawanna and Sparrows Point plants of the Bethlehem Steel Company. In general, the difference is not too great.

A few weeks ago the Lackawanna plant received a copy of this paper and after examining it, it was decided to have the electrical contractor apply it to seven new cranes being wired. The cranes use motors of the new 600 series.

Table XXV is a tabulation showing the size crane wiring for the older type of Westinghouse MC 20, 30, 40, etc., series of motors used by the Lackawanna and Sparrows Point plants, in addition to the proposed AISE standards for average and heavy duty service.

Frank Cramer: One thing that the committee discovered in preparing these figures was that plant repair departments had a habit of taking care of things themselves, especially on the motor lead sizes. They developed their own standards, which were never advertised, and it is surprising to hear Mr. Angel citing some of the figures they use which compare very favorably with data dug up by the committee.

W. P. Lewis: This matter of short time rating of electrical conductors in many plants that we service is something that the wire manufacturers have been slightly reluctant to attack. You can understand that a

TABLE XXIV

(This comparison tabulates frame lead, steel plant, and proposed standard conductor sizes for mill type motors. As a matter of interest, the typical steel plant conductor sizes most closely approximate the proposed standard.)

Frame size	1 Hp ½ hr	2 Amp ½ hr	3 Hp 1 hr	4 Amp 1 hr	5 Frame lead size	5A Lackawanna plant B. S. Co.	5B Sparrows Point plant B. S. Co.	6 Table XIX, heavy duty RH-75 C	7 Table XIX, average duty RH-75 C	17 Typical steel plant
2	6½	29	5	21	6	6	8	8	8	8
3	10	44	7½	31	6	6	6	8	8	8
4	13½	57	10	40	6	6	6	8	8	6
6	19	77	15	57	5	6	4	6	6	6
8	33	126	25	95	2	2	4	2	4	4
10	45	175	35	132	1	1/0	2	1	2	1/0
12	65	245	50	185	1/0	4/0	1/0	2/0	1/0	2/0
14	100	368	75	272	3/0	300	2/0	4/0	3/0	4/0
16	135	500	100	360	250	300	250	300	250	350
18	200	740	150	540	400	500	500	500	350	500
20	250	960	200	730	650	...	...	2-300	500	2-300

TABLE XXV

Conductor Sizes for Westinghouse MC Type Mill Motors for Overhead Traveling Cranes

	Heavy duty service								Average duty service						
Frame size	1 Hp ½ hr	2 Amp ½ hr	3 Condr size per leg	3A Lacka-wanna plant B.S.Co.	3B Sp.Pt. plant B.S.Co.	4 Conduit size, in. & No.	5 Amp RH 75 C	6 Amp AVA 110 C	1 Hp 1 hr	2 Amp 1 hr	3 Condr size per leg	3A Lacka-wanna plant B.S.Co.	4 Conduit size, in. & No.	5 Amp RH 75 C	6 Amp AVA 110 C
20	7½	34	8	6	6	1¼	60	80	6	25	8	6	1¼	55	73
30	15	62	6	6	6	1¼	86	105	12	47	8	4	1¼	55	73
40	28	116	4	2	4	1½	117	147	20	76	6	2	1¼	76	93
50	40	157	2	1/0	2	2	160	190	30	114	3	2	1½	120	145
60	65	250	2/0	2/0	1/0	2½	267	331	50	172	1/0	2/0	2	190	239
70	90	346	4/0	4/0	2/0	2½	369	440	70	255	3/0	2/0	2½	280	339
80	110	410	250	300	4/0	3	420	516	85	320	4/0	4/0	2½	295	352
90	140	520	300	300	250	3	582	707	100	360	250	500	3	364	447
100	200	730	500	500	500	3(2)	847	1004	150	540	400	500	3(2)	538	666
			2-250			3(2)	840	1032			2-3/0		2½(2)	560	678
103	250	900	2-300	.....	.....	3(2)	1164	1414	180	660	2-250	.....	3(2)	728	894
165	325	1160	2-400	.....	.....	3(2)	1376	1912	275	970	2-350	.....	3(2)	972	1232

user of the product is in better position to evaluate the limitations than is the manufacturer of the wire which may be used.

The American Institute of Electrical Engineers, the Insulated Power Engineers Association, the Association of Edison Illuminating Companies, to mention three of the prominent bodies, have devoted themselves almost entirely to continuous ratings.

Our chief electrical engineer, W. T. Peirce, has been working on the matter of crane ratings for some time, and has accumulated a mass of material for cranes in the various classes and sizes. The complexity of the problem has made it very difficult for the wire manufacturer, who does not have sufficient amount of data on actual operations, to make up a complete study of this problem.

I have a number of recording watt meter charts which we collected, and I want to point out that the actual experiments in the various U. S. Steel Corp. subsidiary plants follow very closely the ratings and time cycle information which have been chosen by Mr. Dimitt and his committee. I think that the conclusions which they have reached are very sound and will bear use throughout the steel and other industries which use traveling cranes.

The classifications which have been set up may seem to some of you to be too involved and too ramified, but we have charts which show operations of those various characteritsics in various plants.

Marc de Ferranti: This fine report presents more informative data than has appeared on this subject at any time previously so far as we know.

As electrical manufacturers, we are interested in having adequate wiring, to insure good performance of the crane, but at the same time recognize that the use of National Electrical Code "continuous rating" conductors for short time rated motors frequently was a hardship on the crane builder and an unnecessary waste of copper. Although many crane specifications have been written to call for wiring "in accordance with National Electrical Code," I venture to say that most crane builders would find it hard to determine exactly how this code can be applied satisfactorily to the conditions on a crane.

The initiative of this sub-committee in setting up standards which will serve as a guide for the application of crane wiring, will be appreciated by all concerned with the design and manufacture of cranes. Our review of the data, leads us to believe that the proposed standard cable sizes will give very satisfactory installations. We will also welcome the opportunity to join any discussions regarding motor lead size standardization.

C. B. Hathaway: This thorough report represents a great amount of tedious and careful work. Since the standardization of cables between the motors and control on cranes does not affect motor manufacturers, I shall restrict my comments to the problem of sizes of cables inside the motors which are used for connections between field coils and between these coils and the brushholders or motor terminals.

Mill type motors are designed as compactly as good practice will permit. All connections between the upper and lower half frames are brought to the outside of the motor to facilitate maintenance. Thus both the cables to the field coils on the side away from the lead side are in the same bundle. This results in twice the number of cables in the bundle compared to that in a motor having a solid frame. Therefore, the size of the cables in a mill type motor should be as small as the carrying capacity will permit.

It has been our observation that there has been a trend toward larger cables inside the motors. It is of interest to note that we are now using lower current densities in the newer AVA cables than we used in rubber insulated cables twenty-five years ago.

It is suggested in the report that any desire to consider standardization of the size of cables in mill type motors might be more properly taken up by the committee on motor standardization. We shall be very glad to cooperate with this committee if they desire to study this problem.

J. N. Hartzell, Jr.: This paper represents a long-needed standard and I certainly hope it will be adopted as a permanent part of the Association of Iron and Steel Engineers' crane specifications in the very near future.

This paper has suggested a maximum size for conduit, namely, 3 in. In some cases this necessitates using two lines of conduit for motor conductors, but if 3½ in. conduit were used, only one conduit would be required. This may seem to be an insignificant point but, with the close critical clearances required in crane building

today, the economy of space becomes very important. Obviously one 3½ in. conduit consumes less space than two 3 in. conduits. Perhaps an alternate could be included allowing the crane builder a choice of two 3 in. or one 3½ in. conduit as conditions and clearances might dictate.

This paper has already emphasized that additions or modifications may be required. I agree with this statement wholeheartedly. However, I would like to see alternating current motors and associated wiring added as part of the standard before its final adoption. I believe there has been as much and possibly more confusion involved with wiring for alternating current motors than there has been with direct current motors, and the need for standardization of either one is equally important.

It seems to me that the problem of wiring, whenever discussed, always omits a point, which I consider worthy of mention. This paper treats motor lead size, conductor size, duty cycle and type of insulation. However, no mention is made of conductor size or type of insulation for the wiring between the control panel and accelerating and/or dynamic braking resistors. I feel that this point is very important and therefore hope it will be considered for study as a possible addition to the proposed standard.

Bohdan Yagello: The crane of today is a highly specialized piece of equipment, one that has problems of wiring not ordinarily encountered on stationary equipment. Here, the space consumed by electric motors, controls, resistors and wiring is a substantial part of that of the crane. Consequently, the determination of wire and conduit sizes for electrical machinery intermittently rated for crane use has been a much discussed problem by the crane manufacturers and the ultimate users of these cranes. In the days long gone by, the matter of wiring was left up to the crane manufacturer but with the advent of a more plentiful supply of trained experienced steel mill personnel, the subject of wire standards and mill practices has gradually filtered into crane specifications. These, of course, varied considerably from user to user hence the supplier came into possession of numerous standards different from his own. Although this practice facilitated the wiring of a particular crane, the overall picture of standardizing wire sizes was not improved. If anything, the picture became more confusing when the differences of opinion were compared.

Our wiring experience set up a minimum of a No. 12 stranded wire for control circuits, and a No. 6 stranded wire for all mill motor power circuits. Obviously for many sizes of motors, the No. 6 wire is much too heavy, but this size was adopted as our practical minimum.

On heavier sizes of wire, the covering was changed from Type R to Type RH which increased the permissible maximum operating temperature and the life of the insulation as the rating of the wire was kept to that of the Type "R." The size itself was based on the full load current of the ½-hour rating of the motor and was, from experience, taken to be a wire size whose continuous rating was approximately 60 per cent of the intermittent full load motor current.

A comparison of this determination with the 1947 National Electrical Code shows that on the larger sizes of wire, those from about 300 MCM upwards, this method equals or betters the code. However, on smaller sizes, the 30 and 60 minute ratings of wire under the crane section of the code approach the continuous ratings of the wire. In other words, the rating multiplication factor "K" for intermittent service varies from near unity on small wires to over two for those about 500 MCM. This variation in "K" factor is always a controversial subject for discussion.

Coupled with the "K" factor variation is the lack of differentiation between the 30 and 60 minute wire ratings. Older codes stipulated 90 per cent of the continuous ratings for intermittent service, and this stringent provision was rarely if ever followed in steel mill practice as evidenced by the numerous mill standards available. Within the past few years, as a compromise between the earlier issues of the code and our experience, our cranes have been wired at approximately 70 per cent capacity for increased safety factor in wiring.

It is no wonder then that this report is creating such interest among builders and users of cranes. The builders want as small wire as possible consistant with duty cycle, so as to pipe and wire the crane in a manner that facilitates erection and maintenance, at the same time not covering the crane with piping of outlandish size and in makeshift locations. As all of us here know from experience, the electrical equipment and wiring is the last portion of the layout and design of a crane, and the electricians have only the space left by others for wiring. According to this specification, there will be a uniform method established for all crane manufacturers to follow provided that the specifications are simplified more so than at present, or that the purchaser absolutely furnishes all the information relative to duty cycle, type, use, service conditions, etc., that will positively classify the crane for proper wiring choice. Through this specification, there is no longer a question of the suppliers attempting to wire a crane to suit the purchaser; the user now definitely indicates how the crane is to be wired, thus straightening out any differences in opinion. Through logical application of a specification agreeable to all, the purchaser will ultimately obtain a machine adequately wired, with neat conduit runs of proper size and without awkward offsets, and a wiring job which is safe from a maintenance standpoint and is easy to service.

J. D. O'Roark: I think we are all interested and impressed with the amount of work that goes on behind the scenes, which most of us members of the Association of Iron and Steel Engineers do not know too much about until the papers are presented, and then the degree and magnitude of the work that these men have done is very outstanding.

In listening to the talk about standardization of cable sizes to be used, I have been wondering if we should not go a little farther and consider the degree of stranding. I do not believe that was brought out. In some cases the coarse stranding cable is very stiff. Sometimes, due to vibration, there is a tendency for it to break and chafe through the insulation sooner than the finer-stranded cables.

I should like to go farther on this wiring matter. Should we consider specifying soldered lugs or mechanical terminals? Some cranes are partially wired when they leave the factory, particularly the trolleys, so, should we say that soldered lugs should be used, or will be accept mechanical terminals?

There are a lot of mechanical details of installation

that I believe ought to be given some thought. No matter how carefully we select the wire sizes, the stranding, or the terminals, unless the wiring is installed reasonably securely, may cause trouble to develop in short order, so I would think that we might specify that all conduit bushings be made of fibre, screwed fittings, and even go so far as to use a setscrew in the fibre bushing. Many times the bushing comes unscrewed, and the wire chafes over the end of the conduit, and we have grounded and sometimes shorted conductors, and the leads are burned off.

I think we might also specify that all wiring in junction boxes be securely lashed so that a minimum of conductor vibration can occur in those junction boxes. We might further specify on our resistance wiring that it also be firmly and securely supported and lashed in place, and although on many cranes the completion of the wiring is done in the field, I believe if the crane builder would supply permanent lead marking tags which could be applied to the leads coming out of the conduit, once the direction of the motor is determined, a man would not have to fuss around with paper marking tags, or nicking the wire with his knife, or other practices that motor inspectors usually resort to if a motor has to be changed at a later date.

Bohdan Yagello: In regard to the problem of holding the insulated end-bushings onto conduit ends and that of using a bushing with a set screw, a little cement in the form of the red glyptal on the threads will hold the bushing in place under practically all conditions. Rarely if ever will the set screw type of bushing be needed; even that type is subject to loosening under extreme vibration. To attempt an adoption of the set screw type of bushing because of one need in several hundred merely raises the cost of wiring and who can guarantee that the bushing will be screwed on tight and the set screw properly set if at all.

Relative to lead markings, you will find that ordinarily lead marking tags on cable ends are not used except at collectors and when these are marked, they are marked up as motor connections subject, of course, to change by the user to agree with any standard prevailing in his particular plant. As these do not agree from plant to plant, a standard on lead markings is only effective on cranes built to AISE specification and even then will not agree with plant standards until these plant standards are revised. This in itself may constitute a radical change.

There is another question I wish to bring up that was not too well taken care of beforehand in the previous discussion; that question is the one pertaining to the ampere rating of wire in conduit for a four-wire feeder system. The code stipulates a derating factor of eight-tenths for 4 to 6 wires in conduit. To eliminate any opinion differences, I should like to see permission granted by the code to use a derating interpolation factor of 94 per cent for four wires, 87 per cent for five wires and then the 80 per cent for 6 wires. With such factors the proper wire and conduit size can be determined for any particular application. There should also be less emphasis by the users on the code sizes of conduit when this conduit is open ended and used merely to support cables such as are encountered in resistor wiring. On these very short runs a multiplicity of half-empty conduit shows lack of consideration for design and practicability.

C. E. Dimitt: It is interesting to hear Mr. Angel's comments regarding the close relationship between the proposed standards and the motor lead and conductor sizes used at Bethlehem plants. It is also gratifying to hear that the proposed standards have been used as the basis for wiring seven of their cranes. We shall await with interest the results of these applications. Perhaps some data will be available for discussion at our next convention.

In connection with Mr. Hartzell's comments regarding conduit size, we have found that some plants object to the use of 3½ and 4½ in. size conduit. As mentioned by Mr. Hartzell, the objective in crane wiring is to get the best mechanical job in the limited space available. The lesser radius of a 3 in. conduit elbow usually results in a better arrangement than a 3½ in. elbow. Also, the use of multiple conductors of smaller size results in smaller conductor bending radius and ease of handling conductors during installation and when making motor replacements.

Mr. Hartzell has suggested that conductor size standards be developed for a-c motors. If there is general interest and desire for this development, we believe the chairman of the Standardization Committee should be requested to include this item in the wiring committee's agenda.

We agree with Mr. Hartzell that something should be done about standardizing on conductor sizes for resistor wiring. This item has previously been included in the wiring committee's agenda for future action.

Mr. O'Roark has mentioned something about conductor stranding. The proposed standards specify standard stranding. If any plants have found it difficult to install standard stranding, and have gone to a more flexible stranding, the wiring committee would be glad to receive pertinent data.

Mr. O'Roark has suggested a number of items for consideration which have previously been included in the wiring committee's agenda for future action. These items are types of lugs and terminals, types of insulated bushings, marking of leads, security and support of wiring at panels, motors, and resistors, and in junction boxes. We also believe something should be done about junction boxes. The use of standard conduit fittings frequently requires the bending of conductors so sharply that the insulation is broken before the crane goes into service.

Mr. Yagello has inquired about the use of factors for 4, 5, and 6 conductors in a conduit in accordance with National Electrical Code standards. The wiring committee's proposed standards and conductor ratings are based on the use of four conductors in a conduit, and the curves included with this report compares the results of tests made with three and four conductors. Based on these tests, we agree that the 0.8 multiplier is too great for four conductors in conduit for intermittant duty motor wiring.

Frank Cramer: I think as a matter of information you may be interested to know that this work will be done in conjunction with a committee who are now revising a section of the National Electrical Code, which pertains to crane wiring. We have been invited to have a representative on that committee, and we are hoping that a lot of these results will appear in the next issue of the National Electrical Code so far as it concerns crane wiring.

Roller Bearing Application

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. . . . to obtain maximum life for mill bearings it is essential that the bearing be properly selected and designed, and carefully maintained . . . . finally, no factor will shorten bearing life more rapidly than overloading . . . .

▲ THE requirement for effective economical mill operation at the point of application of roller bearings is a very important factor for consideration by each and every individual responsible for the product, its purchase and mounting. For more than 20 years, and particularly during the past emergency, the combined creative effort of the mill operator, equipment builder and bearing manufacturer has produced equipment very much in line with precision standards. These precision standards, and their relationship to the pattern of operations today, automatically introduce requirements for preventive maintenance of roller bearing application to gain maximum service efficiency at minimum cost.

The bearing manufacturer is basically responsible for a product which will meet conditions of service. Special materials, heat treatment, finishing and inspection of the bearing elements are critically controlled for uniformity. Roller bearing quality standards require expensive tools and accurate control of size and tolerance for each bearing element at final assembly.

The bearing manufacturers are striving to design and manufacture roller bearings of all types and sizes to increase shock and impact resistance. An example of this has been described by Paul Haager in a paper published in the 1946 Proceedings of the Association of Iron and Steel Engineer, P 624, entitled "Development of Balanced Proportion Roller Bearings for Rolling Mills."

"Balanced Proportion Roller Bearings" allow for maximum roll neck diameters with minimum bearing cross-section. At the same time, maximum radial capacities are possible with this bearing to take care of shock and impact loads.

For work roll bearings, where thrust loads are encountered, revisions have been introduced to increase the angle of roller-raceway contact so that maximum thrust capacity is available. Minimum bearing angularity for the rollers of approximately 10 degrees will permit maximum radial capacity, whereas roller angularity of 20 to 25 degrees will produce maximum thrust capacity.

In some cases, the increase of the bearing angle has been limited, due to minimum cross-sections required for relationship of roll body and neck diameters. To meet these limitations, design features related to control of angles have been introduced. In addition, it has been possible to reduce bearing race sections because of the development of better materials and heat treating procedures. Equal performance under many repetitions of stress is thus secured with minimum bearing race sections.

It is possible to develop bearings of types and sizes to meet any condition of load, but in most cases, the limiting factor is introduced by the initial cost and the massiveness of the equipment.

It is necessary to introduce a theory of life expectancy to give equipment builders some idea how long a bearing will last under known conditions of application and operation. To make life prediction, there must be an evaluation of conditions in terms of their effects upon the bearings. There are many factors to be considered, and these are presented as follows: load, speed, shock or impact loading, corrosion influence, accuracy of mounting, temperature, lubrication, sealing, etc. Some of these factors may be easily formulated, while others present greater difficulty. Frequently, the presence of errors in assessing these values causes considerable disagreement between the computed and the actual life of a bearing application. The combined experience of everyone can promote favorable considerations for selection of bearing type and size to result in maximum service life expectancy.

Preventive maintenance associated with roll neck bearings is well known. Yet very little is done to promote proper procedures to take advantage of every dollar invested for the bearings.

Everyone associated with the steel mill industry can

well be proud of the motor room because of excellent housekeeping. On the other hand, the conditions in most of the bearing and roll changing departments cannot be considered acceptable for proper bearing inspection and assembly. It is remarkable that service life results from bearings are on the records as they are today. Cost figures are much higher than they should be.

Life expectancy results are going to vary because of factors previously presented, but there is absolutely no necessity to add variables which will shorten bearing service life. Bearings are received at the mill fairly well packaged and protected. Equal protection must be maintained as long as the bearings are serviceable. Chocks, shafts and adapters for bearing mountings must be handled with proper tools to assure correct fits for an accurate assembly.

An out-of-round chock or bearing housing will not permit the load distribution required to take advantage of the capacity built into the product by the bearing manufacturer. Adapters and spacer rings which are excessively out of concentric or out-of-square will not permit satisfactory positioning of the bearing elements.

Roll neck mountings allow for loose fit at the bearing bore and outside diameter to facilitate mounting and roll changes. Under these conditions, squareness of adapter rings, spacers and locknuts is more critical than that required for the standard bearing mounting where interference fits are introduced at the bearing bore under conditions of shaft rotation, or at the bearings outside diameter under conditions of outer race rotation.

The uniformity of roll neck diameters and concentricity with roll body will allow for good performance of the bearings and also the roll. Shoulders for spacers, bearing race contact surfaces, grooves for clamps and locknuts should also be square with the axis of the roll. This is particularly true on re-hardened rolls because of distortion during heat-treatments.

With correct details for housings and shafts, the next factor in assembly to the equipment is the alinement of shaft for minimum angularity. The first consideration can be established at the base of the mill housing window where the bearing chock is supported. The height at this position in both mill housings should be the same. Variation in height can be corrected by shimming to correct level at the pass line. Semi-annual check for variation in the level between the two mill housings at this point will show some deviation each time, which will require correction, but the difference will vary from stand to stand, depending entirely upon the type of operation.

With correct level, the vertical or screw centerline through the mill housing and roll positions must be maintained. This condition is usually controlled by replaceable wear plates on the chocks or guide surfaces which are positioned to maintain roll axis on the established vertical centerline.

In some mills, an off-set is used for rolls because of operating conditions. This arrangement requires attention for proper positioning of chocks because the off-set may be as much as $\frac{3}{8}$ in. Incorrect mounting with off-set rolls will create cross-roll condition and excessive thrust loads.

When crowned rolls are used, contact area established at the angle of the crown will create a force in line with the axis of the roll. Therefore, it is very important to have the high point of the crown matched with its mating roll, so that excessive thrust loads are not applied to the bearings. For the same reason, the clamping of the chocks to the mill housing must be controlled accurately to assure contact of maximum roll diameters at the high point of the crown, so that they mate on true center position.

There is always a condition of creep on bearing inner races on roll necks which results in neck wear. Experience has proved that there is no known method of keying or locking against the condition of creep. It is therefore necessary to allow sufficient clearance between bearing bore and roll neck diameter so that the grease or oil in the bearing may establish a film of lubricant for fluid friction.

With no lubricant film at the bearing bore, the high unit pressure of contact will generate considerable heat because of friction between two dry surfaces of metal moving at different speeds. Preventive measures have been used for many years with fair results. One method incorporates a rotary fitting at the center of the roll which is drilled to the depth of the bearing inner race center line. Radial holes are then positioned to grooves in the roll necks at the center of the bearing inner races. Lubricant is then forced through to the bearing bore. The standard practice is to provide alternate grooves and hard facing in the fillet spacers and clamping rings at each end of the bearing inner races and thus allow flow of lubricants to the bearing bores at each position.

Experience has definitely proved that oil lubrication will prevent excessive neck wear and scoring. Consideration should be given to use of lubricants with low viscosity to allow flow to bearing bore, but at the same time, it is necessary to establish the lubricant viscosity so that it is possible to prevent leakage through the seals. Seasonal temperature variations introduce a requirement for change of viscosity of lubricant and this is more or less standard mill practice at the present time.

The question comes up from time to time regarding the allowable amount of neck wear for satisfactory bearing service. Many figures have been established, but experience of operation is the best answer. Some applications have been found with as much as $\frac{1}{8}$ in. wear or difference in diameter. The clearance at the bearing bore becomes quite critical on high speed mills, and, in all cases, it should be held to a minimum for satisfactory roll life. On roll necks which are built up by various methods of weld or metallizing, the clearance should be established at the maximum initial clearance to allow for film of lubricant at the bearing bore, and thereby prevent rupture of the new metal surface.

It was previously pointed out that roller bearings must be protected for their full service life. We will repeat that regular intervals of inspection are desirable, and usually result in dividends returned because unnecessary down-time is fairly well eliminated. Preventive maintenance on bearing applications must be based on complete degreasing and inspection at intervals of hours of operation or tonnage rolled.

One of the most important preventive measures in bearing maintenance relates to outer race rotation, particularly with back-up roll bearings. The outer races of the roller bearings are subjected to a load area of

approximately 72 degrees of the race-way circumference. By rotating outer races at regular intervals of inspection, bearing service may be increased two to four times.

Work roll bearings are not subjected to excessive radial loads although thrust load is present. These bearings may be turned end for end to distribute the thrust load on all raceways as much as possible.

Roll neck bearing tonnage records are of a highly controversial nature. Still, despite the range of load from peak stage for some stands to low figures elsewhere, it is possible to keep significant records of number of hours of services or tonnage rolled. Basically, the life of a bearing is independent of speed when measured in number of revolutions. Consequently, a direct relationship can be established between service life results secured with bearings in slow speed stands and bearings in higher speed stands near the end of the finishing train. A similar relationship can be established for load conditions in different stands.

For each stand on cold or hot mills, it has been suggested that a factor be applied that would encompass speed, load and time under load. Accuracy in determining the factor is important. It has been found that the hours of expected life vary approximately as the cube of the quotient of the bearing capacity divided by the applied load. Thus, if the applied load should be only half of that calculated, the life of the bearing will be increased about 10 times.

With the application of such a factor, service life records should be based on an *average* tonnage or hours of service. There are many service records today which accurately reveal the tonnage rolled or the number of hours of service for each bearing in a mill. At the same time, it is desirable to have an accurate record of bearings that have been scrapped after serving their life. The average tonnage figure on these bearings will indicate whether some gain has been made over previous years of service.

Tonnage records should be as simple as possible to avoid excessive costs in keeping them. Yet they must be detailed enough to show a true and accurate picture of bearing quality and operating costs. A straight tonnage record kept without regard to load and number of revolutions is of little value. Together with normal conditions of operation, all abnormal conditions must also be recorded in the service record of each bearing, to indicate clearly the reason for service life variation and thereby introduce preventive measures to eliminate such abnormal factors. Some of the abnormal conditions of operation are broken rolls, cobbles, crossed rolls, improper alinement, insufficient lubrication and others which have been previously covered.

A very good reference book on roll neck bearings is available for study, entitled "Roll Neck Bearings — Design, Construction and Operation," by L. R. Underwood, Chief Engineer Officer, Technical Department, British Iron and Steel Federation. This book covers a report to the rolling mills research sub-committee and the rolling mill committee of the Iron and Steel Industrial Research Council, dated 1943.

From this reference, the following data is quoted relative to the subject of lubrication. The functions of a lubricant in a roller bearing are: to minimize internal sliding friction in the bearing; to protect the highly polished rollers and races from corrosion; to dissipate heat generated by deformation caused by the loads carried on the rollers and races; in the case of rolling mills to dissipate the heat conducted into the bearing by the roll neck when oil is used as the lubricant, and to equalize the temperatures when grease is employed; to act as a seal against the entrance of dirt, steel, water, etc.

Roller bearings on roll neck may be lubricated either by hand-gun or by mechanical lubricators with either grease or oil.

According to "The Modern Strip Mill", published by the AISE, bearings over 6 inches in diameter which operate at 500 rpm or more are better lubricated with oil. With the increase of delivery speed, particularly on the new cold mills, oil lubrication could be introduced for better bearing performance. Oil lubrication for hot mill applications may also be desirable because a circulating system would provide adequate cooling. In most cases, it is concluded that only exceptional circumstances, such as high speeds and temperatures, require an oil lubricating system for efficient lubrication and cooling of roller bearings.

Three main types of greases are used, according to the operating conditions, lime base grease, soda base grease and extreme pressure grease. The lime base grease is widely used in roller bearings for roll necks and is generally of a soft consistency, having a melting point between 160-210 F. In order to insure a stable product, a water content of 1-3 per cent is necessary, and if this grease is used in a dry, hot bearing, evaporation of the contained moisture results in separation of oil and soap. This effect is not very marked with modern grease. This grease is particularly suitable for bearings into which water might find its way, as the insoluble lime soap forms an effective seal against the entry of water. Its soft consistency enables it to reach all parts of the bearing elements. The grease must be of such quality to prevent separation of oil and soap because of churning action of the rollers. The accepted specifications for lime base grease is that it must be a smooth well-manufactured product, composed of a high-grade lime soap and a refined mineral oil. It shall be free from corrosive matter, grit, resin, waxes, talc, mica, graphite, clay or fillers of any kind.

The soda base greases are usually of a fibrous nature and have a melting point in the order of 275-300 F, which is much higher than that of the lime base greases. Soda base greases are therefore suitable for high-temperature applications. In the presence of water, these greases will emulsify, so they are not recommended for bearings from which water cannot be completely excluded. The emulsion is a good lubricant, but there is a danger of corrosion if the bearings are left standing for a long period. With soda base greases of low soap content, there is a comparatively high initial peak temperature owing to excessive churning caused by their tenacious nature. They will, however, withstand a certain amount of oil separation without hardening sufficiently to cause trouble. Soda base greases of high soap content give a lower initial peak temperature, but only a slight oil separation is allowable, otherwise, the grease becomes too hard and cannot reach all bearing parts. Soda base greases are considered desirable in mills operating at high speeds and temperatures.

Extreme pressure greases are highly desirable in mills

where bearings are subjected to high loads and severe shocks in order to prevent, or reduce to a minimum, scoring of races or wear of rollers. Extreme pressure greases usually contain components which are not completely inactive chemically. It is therefore necessary to make sure that the lubricant proposed does not corrode the highly finished elements of the roller bearing. Authorities have indicated that where bearing seals do not prevent the entrance of excessive amounts of water, a specially compounded sulphur base type of grease may be used with good results. While the extreme pressure product is more chemically active than the lead soap type, it has not caused complaints on corrosiveness where it has been applied. The particular feature of such a product is its increased resistance to emulsification with water and consequent foaming.

The same authority also mentions that a special lime base grease, into which a lead soap has been properly incorporated, constitutes a satisfactory type of extreme pressure grease. Other types of extreme pressure grease which have been giving good results are lime-lead-soap-sulphur products, as well as the lime soap sulphurized base, and lead-soap-sulphur-chloride base materials. Carefully selected extreme pressure grease in most mill applications is advocated, since in lightly loaded mills, it can do no harm, and, in heavily loaded mills, it is definitely beneficial.

In the initial packing of the bearings and housings, the volume of grease must assure satisfactory lubrication until more lubricant can be added. The initial filling with lubricant should be to approximately 30 to 40 per cent of the total volume. Small quantities of lubricant added at frequent intervals are preferable to large quantities added infrequently.

Failure of grease lubrication is generally attributable to one of the following causes:

1. Escape of grease due to insufficient sealing of the housing. (In some roll neck applications, grease is supplied at such a rate that it seeps out slowly past the seals. This is done at times to prevent the ingress of dirt or water into the bearing. Failures are not likely to occur in mills where this practice is followed.)
2. Evaporation of oil from the lubricant due to high operating temperatures.
3. Too large a space in the housing, allowing the grease to be thrown clear out of the rotating parts.
4. The initial application of too much grease in a housing resulting in oil separation.

The use of vent plugs on housings will allow for some relief at the seals so that they may be more effective in keeping out foreign materials.

It might be well to consider an efficient lubrication program which would include personnel familiar with the equipment, and also a lubrication engineer representing the lubricant supplier. Lubricant manufacturers have developed charts covering the specifications for lubricants used in the automobile; consequently, there should be no objection to developing similar charts for equipment in the steel mill plant. Such a program may reduce the number of types of lubricants needed for central storage and control.

Another important factor in preventive maintenance relates to grease and oil seals required for the protection of the highly finished surfaces of the bearing elements. The degree of protection secured will automatically affect the ultimate service life of the bearing. Selection of the seal is therefore important, since their protective properties vary from one type to another.

Seals are important, not only from the standpoint of protection for the bearing elements, but also from the standpoint of protection against contamination of the materials being processed on various applications.

Many features of accuracy in assembly, as related to the roller bearings, are applicable to the seals. Friction type seals are limited to service applications where high speeds and temperatures are not encountered. Under these extreme conditions, it is necessary to consider the use of piston ring type seals or labyrinth construction where a combination of flingers and flanges is used.

There are many other details involved in roller bearing application, lubrication and sealings. It is therefore suggested that such information be obtained from representative engineering staffs of manufacturers specializing in those fields. Specific recommendations of products suited to individual operating conditions can be secured that will assure the best performance for the investment.

DISCUSSION

PRESENTED BY

RUSSELL LYONS, Service Engineer, Timken Roller Bearing Co., Canton, Ohio.

JOHN A. TOTH, Chief Engineer, The Torrington Co., Bantam Bearings Div., South Bend, Ind.

H. F. JACQUART, Master Mechanic, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

N. I. WHITELEY, Lubrication Engineer, American Steel & Wire Co., Cleveland, Ohio.

A. S. MURRAY, Assistant Chief Engineer, SKF Industries, Inc., Philadelphia, Pa.

H. H. WOOD, District Manager, Morgan Construction Co., Pittsburgh, Pa.

C. E. PRITCHARD, Chief Lubrication Engineer, Republic Steel Corp., Cleveland, Ohio.

Russell Lyons: Reference was made to the magnitude of radial load on work roll bearings and I agree with that as far as the rolling load is concerned, but I am wondering whether we overlooked the jack pressures which held the work rolls against the back-up rolls. In making a survey of the situation, some years ago, we found mills where the jack pressure ran as high as 76.6 per cent of the work roll bearing rated capacities before they started doing any work, which is a considerable radial load. I just wanted to get clear on that.

John A. Toth: That is true. At the same time, you can take bearings out of a mill for inspection and, I am sure, you have found this to be true, in most cases the failures that you do find are primarily due to thrust condition of loading. You may find one or two races that are badly spalled, while on the other two, we sometimes find the original grind-marks in them.

Russell Lyons: That is true in most cases. We found that, any time the jack pressure exceeded 50 per cent of the bearing-rated capacity, the failures went up in direct proportion to the amount over the 50 per cent and, in some cases, there was very serious failure because of the jack pressure alone.

H. F. Jacquart: I would like to ask what type of

mill encountered this wear, and how did they overcome the chattering and scuffing that must have resulted?

John A. Toth: The one-eighth wear on the roll neck was found on a hot mill back-up roll neck. The chattering, or the condition that you speak of, was not overcome. Various methods of metallizing have been tried. As far as we know, none of these have proven satisfactory. The metallizing is applied to the roll neck, to a diameter greater than print size. The roll neck is then ground to size for final bearing assembly. In service, the new metal surface checks and cracks, to result in greater damage than that experienced when wear is permitted for maximum roll service life.

H. F. Jacquart: You talked about the importance of a good recording program for your bearings to achieve a life expectancy, and, among the various different factors that you mentioned, I thought the type of product rolled should have come into one of those factors in trying to establish that life expectancy. For instance, we try to set the screwdown at the South Side to roll 0.048 in. section and the thrust on the mill is terrific.

John A. Toth: In your mill operations, you will find that the bearing life will vary. The tonnage records must include the factor of material being rolled, particularly on light gage section. There is one operation where standard steels are rolled. In addition, various alloys and stainless are rolled. These immediately develop factors pertaining to bearing tonnage life expectancy because of lack of uniformity in loads and speeds.

The 0.048 in. section given by you will introduce a related variable as that encountered with alloys and stainless steel. These details should be considered in all cases, to obtain a fair and true picture in the overall program.

Now, if you were going to operate your mill for light section, alloy or stainless steel production, the mill would be entirely different from the type of mill you are using now. It would be much heavier for higher bearing factors initially, to offset the overloads encountered.

N. I. Whiteley: I have one comment to make on the life expectancy which is calculated in bearings. The saying around steel mills is that we no sooner get a new mill built, and, before the cement is dry, we immediately start to figure out how we can increase the capacity of that mill. That is more truthful than poetical, because the load factors are all figured to run at certain loads. Then we increase that load by increasing production and the same bearing is supposed to take the load; either the bearing gets blamed or the lubricants get blamed, in place of the actual fact that the mill was never built to carry the load in the first place. I think that situation is very prevalent, particularly during the last five or six years. This was also true during wartime when mills were very much overloaded. We have one mill that was designed to carry certain loads and they tried to roll wider stock on it. We had not lost a bearing on that mill in over a year or more, and then we lost five bearings in one week because the load would not carry it. As soon as we recognized that factor and took the load off the bearings, bearing loss was stopped. When you are figuring life expectancy, you are figuring on the original load the mill was designed to carry. So, it is not the fault of the bearing manufacturer or the lubrication that caused that bearing to fail, it was just overloaded.

H. F. Jacquart: I wonder if anything new has been developed in the field for back-up thrust bearings?

John A. Toth: Do you mean anti-friction bearings? In addition to the present bearings you are using and supplied by the various companies, there is nothing more that can be done, based on the designs of the bearings and the space limitations of the chocks.

A. S. Murray: I would like to comment on the subject of back-up roll thrust bearing life in hot strip mill applications. To many of you, it is not any secret that we are very much interested in this subject. I do not know the exact interest behind the question, perhaps it is due to receiving shorter bearing life than expected. There are two distinctly different variations of this particular application now in wide use with back-up roll thrust bearings separate from the radial oil film bearings. There is a substantial difference in the tonnage life of these two mountings, and it is experienced with bearings having exactly the same cage and roller sets.

Recently we had occasion to check the first of the present type of thrust bearings that we began running in Gary six years ago this past summer in the finishing stands of an 80 in. mill. At the time we checked the bearing records, as I recall it, we had lost one bearing but the remainder of the eighteen were still in service. The tonnage life on some of those thrust bearings exceeded six million tons, and, although they have not all run the same length of time, most of them have been in the mill during the rolling of between two to four million tons.

Now, you can get more life theoretically if you put more capacity into any mounting, but we feel that the attained life is very good. There is no way we can give you, or any other bearing manufacturer can give you, a specific answer as to how long thrust bearings are going to last. For example, when you bring the mill down for barrel stock, the actual thrust load is the practically indeterminate function of the crown, the particular set of work rolls, and the tolerances of the work roll chucks versus the back-up roll chucks. On the basis of the record, we feel that we have done a good job because all our oil-lubricated bearings are giving good service. If Mr. Harry Wood is in the audience he can substantiate me on that.

I would like to make one additional point in that we have two fundamental differences. The bearing in the first case is oil lubricated and the bearing is completely enclosed, whereas, in the other application, we have grease lubrication without the same degree of protection. The latter points are well known to have a distinct influence on bearing life, and, of necessity they do have an influence on the bearing life in the second type. The bearing at Gary, although of slightly different dimensions, is of practically the same capacity as the size so widely used in the first applications. Accordingly, the results are comparable and the only reason I cite the Gary application in particular is because it is the oldest and I have the clearest recollection of its tonnage record due to having just gone over it.

H. H. Wood: All that I can add to what Mr. Murray has said is this: The design that we use in applying the

thrust bearing to our radial bearing is such that not only is the roller bearing well protected from dirt and water, and flood lubricated with clean oil, but in addition, the inner race is keyed to the roll neck by a roller key which positively prevents any scuffing of the neck and the surfaces which constrain the inner race endwise. I think that the successful keying of the inner race has quite an effect on the good service experienced with this application.

C. E. Pritchard: One of the problems that has faced the operators of high speed mills, such as the strip mills, is that of roll neck scuffing. We have found through investigation of this problem that apparently an insufficient amount of lubricant is obtained or retained through conventional methods of application in the space between the inner race of the bearing and the roll neck proper. Study in the field indicated that it was common practice when making up bearing and chock assemblies to mount the assembly on the roll neck and then by means of either a hand or powered grease gun to apply the lubricant until it was noted that the lubricant was coming out of the chock at some point in the location of the seals. It was assumed at this point that there was sufficient lubricant to satisfy the bearing requirements during mill operations. Subsequent removal of the assembly showed that this was not the case, but rather that only a very small amount of lubricant actually carried into the space between the inner race of the bearing and the roll neck through the slots provided in the bearing design. Apparently, this condition was due to the resistance offered by the diverting grease slots being greater than the roller assembly, or the seals, with the result that starvation of lubricant in this critical area took place. A similar condition is felt to exist during mill operations where due to high resistance forces set up in the bearing under load — an insufficient amount of lubricant gains entry to the roll neck from the normal bearing reservoir through the slots provided with the result that the roll neck tends to scuff.

Another attendant and contributing factor to the problem is the desire for changing rolls in the minimum space of time. It is a foregone conclusion that this request ties directly into the economics of the mill and must be taken into consideration. We must recognize the fact that, if we have the looseness of fit demanded thereby, we are also going to have a proportional increase in the slippage of the inner race on the roll neck. This then offers an accelerated condition which also increases the resistance forces which tend to adversely affect the proper distribution of the lubricant within the bearing, while adding to the need for more positive distribution, all of which tends to hasten metal fatigue and cause roll neck scuffing.

I would ask Mr. Toth what, in his opinion, might be a recommendation to minimize or eliminate this problem?

John A. Toth: We have been trying to develop an answer to that problem for eighteen or twenty years. As I mentioned in my paper, I know of no method to prevent the rotation of bearing inner races mounted directly on roll necks. I know of one specific application where scuffing and wear has been cut down tremendously by going to oil lubrication of the bearings. Oil lubrication allows for required fluid flow to the space between the bearing bore and the roll neck. When we can do the same with grease by methods which have been tried, the results are not the same. However, as far as I know, the oil lubrication has been one feature that has helped that problem considerably.

N. I. Whiteley: There is one point, brought out by Mr. Toth, that I think was very good, and that was the point on grease lubrication of the bearings, that small amounts at frequent intervals are much better than large amounts at infrequent intervals. That is particularly true on higher-speed operations, and it has been a problem in steel mills for quite some time. It is a problem the lubrication engineer must overcome because the thinking of old time operators in mills is the other way around. They have been doing it that way for twenty-five years and you have to change their opinion from that through the use of centralized systems and means of that sort. That problem has been overcome, to a large extent, but there is still a lot of it that can be changed.

A. S. Murray: Mr. Harry Wood has touched on one of the basic points that was raised by Mr. Pritchard. The latter carefully pointed out that while loose fits facilitate the mounting of a bearing, you do have a compromised condition. Invariably where you have a compromise in design, you are going to have a compromise in results, and of necessity you are going to have to be content with only approaching a solution to the problem. Mr. Wood's point that I am referring to is that his company did not want to put up with the slow turning of the thrust bearing inner races on their seats. The thrust bearings tend to turn more slowly than radial bearings, because the same forces that make thrust bearings creep are not as great an influence as in the case of radial bearings; nevertheless, despite theory, thrust bearings do actually tend to creep.

His company prevented creep by keying, and the only other way to avoid scuffing is to put them on with an interference fit. Until recently the mounting of big bearings with interference fits made a difficult job of dismounting. You could put them on easier than you could take them off, although it was a hard job either way — and for roll changes interference fits were a stumbling block of sufficient importance to make everyone quite willing to accept the compromise of loose fit mountings.

Our company has developed a hydraulic technique for dismounting bearings with interference fits, "Improved Method for Mounting Bearing and Couplings," A. S. Murray, 1948 Proceedings, Association of Iron and Steel Engineers, p 195. I would like to re-emphasize that it is practical to properly mount large bearings with interference fits, and that I have personally mounted a 5100-lb bearing with an interference fit of around 0.012 in. It was dismounted and remounted, just as a demonstration of the hydraulic technique, in ten minutes. Now there is a practical solution to any back-up roll neck bearing changing problem, because it is readily accomplished without large external forces being brought into play. The axial displacing force can be conveniently developed by hydraulic pressures, and the force required is only that large enough to overcome the fluid friction and the axial component of the hydraulic pressure between the tapered bore bearings and the mating tapered roll neck.

N. I. Whiteley: We have had personal experiences with this hydraulic method of applications that Mr. Murray spoke about, so we know it works.

John A. Toth: I would like to make comments regarding Mr. Murray's statements. Many years ago, we found that inner races could be mounted on roll necks with an interference fit, and that they would hold for a certain period of time, depending entirely on the type of operation. Eventually, the interference fit was lost, and the inner race size was metal to metal or a loose fit on the roll neck. This condition lead to much more difficulty than a condition of initial loose fit, because lubrication was not possible between the bearing bore and roll neck diameter.

The hydraulic method suggested by Mr. Murray is a good idea. It works successfully and has been used for quite a few years. As I said, the interference fit is satisfactory for a limited period, but it will not stay put because of a condition of inner race growth under load. The unit stress concentration of the rollers on the outside diameter of the inner race, cause the growth similar to the elongation of strip when cold rolling, but on a very much smaller scale. The loop stress is thus relieved and is independent of the metallurgically stabilized piece.

A. S. Murray: I know of a similar experience where they now have an application of our roll neck bearings. The customer had trouble with the original bearings, presumably mounted with an interference fit, becoming loose on the tapered roll necks. The American Steel and Wire Company has now been running over a year and a half with our replacement application, and they no longer have any trouble with contact corrosion at the interference fit between bearing inner races and roll necks, nor do the inner races come loose.

There are patented ways of overcoming inner race growth, and the one we employ removes at least 90 per cent of the theoretical growth. Our heat treating practice leaves only approximately 10 per cent residual growth, and in actual practice this potential growth never makes its presence felt, even under much more severe conditions and time than we normally get in steel mill roll neck service.

N. I. Whiteley: We did, on this loose slipping, in this particular case. Mr. Murray was speaking about the considerable trouble we were having with neck abrasions due to the chattering of the bearings on the necks. That has been pretty well cured now. There were some other mechanical factors that contributed to that, such as the universal coupling used which has now been changed. At the very start of this trouble, the grease got all the blame. A lot of mechanical work had to be done and it was not the fault of the grease. It has cured our problem pretty well even though it was quite expensive while it lasted.

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ASSOCIATION OF IRON AND STEEL ENGINEERS, 1010 EMPIRE BLDG., PITTSBURGH 22, PA.

A STATIC MAGNETIC AMPLIFIER

for Regulating Circuits

. . . . the magnetic amplifier provides the electrical engineer in the steel industry with another tool which will help to turn out better product more economically. . . .

By H. E. LARSON
and
T. DUNNEGAN, JR.
General Electric Co.
Schenectady, N. Y.

▲ THE development of electric regulating systems, particularly since 1940, has given to the iron and steel industry improved and automatic control of high speed rolling mill drives, processing line drives, and drives for special equipment such as continuous electrolytic tinning and galvanizing lines. The circuits for these regulating systems have been made possible by the use of improved amplifiers. The high power amplifier, such as the rotating regulator, was first presented to the Association of Iron and Steel Engineers in 1940, by F. Mohler, has been largely responsible for the development of these regulating systems, although electronic amplifiers have also been used and developed for systems involving lower power requirements.

The self-saturating, static, magnetic amplifier has now been developed to the point where it promises great usefulness in supplementing or replacing electronic amplifiers for small power requirements, and rotating regulators for medium power requirements. Being a static device and therefore possessing the advantages of no moving parts, no starting delay, sturdiness, and long life, it has great practical appeal.

A self-saturated, magnetic amplifier is distinctly a different device from that implied by the general term "magnetic amplifier." Both are static devices and both employ saturable core reactors, with output and control windings, but there the similarity stops.

Broadly speaking, a saturable core reactor, having a-c output windings and d-c saturating or control windings wound on the same core, answers the definition of a magnetic amplifier. However, this is not a self-saturating, magnetic amplifier. Saturable core reactors or magnetic amplifiers have been known and used for over 35 years.

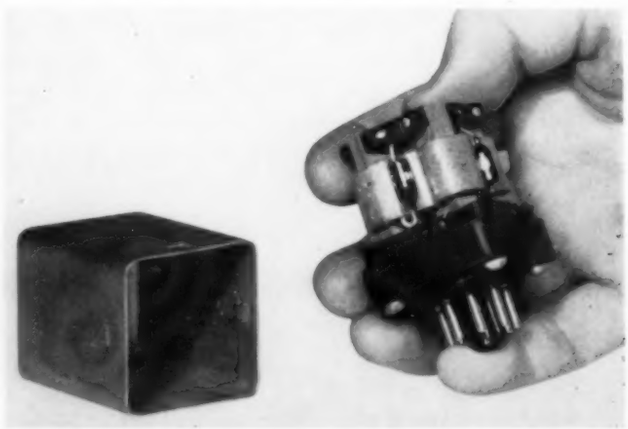
The self-saturating magnetic amplifier includes the use of rectifiers, usually of the selenium or germanium type, in combination with saturable core reactors. The output of this device is always direct current, which flows through the output winding of the saturable core reactor, producing the bulk of the magnetizing force on the core of the reactor. The magnetizing force furnished by the d-c saturating or control winding is usually only a small fraction of that furnished by the output winding, but holds the "balance of power" in saturating the core. When the core saturates, the impedance of the output winding and the a-c voltage induced in the output winding is practically eliminated, permitting a large d-c current to flow through the load. Such a device has come to be known as an "amplistat" and this term will subsequently be used in this article as a short descriptive name for a self-saturating, static, magnetic amplifier.

When the amplistat is properly applied and integrated into a regulating system, it becomes the motivating factor that monitors the entire regulating system. It does so by "sensing" small signals, amplifying them greatly and quickly imparting the amplified commands to the system with decisiveness and stability so that the system can properly adjust itself to the desired standard. This, in brief, is the operation of a closed-cycle regulating system employing an amplistat as the amplifier.

While the name "amplistat" has been used for just about a year, these devices have been built by our company for several years. It is to be regretted that the development of this type of device in this country has lagged somewhat the development in Europe, principally by German and Swedish engineers who have made extensive application of it.

An amplistat is usually considered to be a packaged unit containing the necessary number of saturable core reactors and rectifiers, with suitable terminals. Figure 1 shows the physical appearance of a very small 60 cycle plug-in type amplistat unit rated 1 average volt-ampere. Figure 2 shows the physical appearance of a 100 average volt-amperes, 60 cycle amplistat for base mounting, without cover. For amplistat ratings, say, larger than 100 average volt-amperes, the problem of dissipation of the heat losses, principally in the recti-

Figure 1 — Plug-in type amplistat unit is rated 0.01 average volt-ampere for 60-cycle operation.



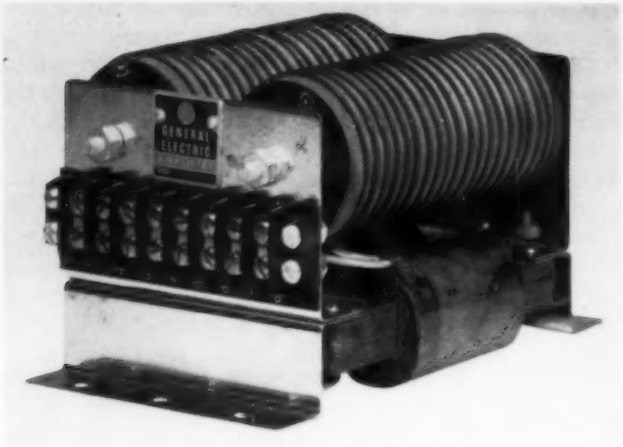


Figure 2 — Base-mounted amplistat unit is shown without cover. It is rated 100 average volt-amperes for 60-cycle operation.

fiers, tends to favor omission of the enclosure, although certain applications make enclosures mandatory.

At this writing, the development of a line of amplistat units has just begun. The predominating thought in the development of the line is to build units which can replace rotating regulators in some regulating circuits. Amplistats, however, can be panel mounted in the same way as the other components of the regulating circuit, such as transformers, capacitors, and resistors. There is a strong tendency, therefore, to package the entire regulating system, particularly in the case of small voltage regulating systems. Such a packaged voltage regulating system is shown in Figure 3. For steel mill applications, however, the present practice is simply to mount the amplistat unit on a panel together with other components of the regulating circuit.

OPERATION

To gain an understanding of the operation of an amplistat, a physical conception of the components involved and their connections should be obtained by reference to Figure 4. Figure 4 shows a circuit for an elementary self-saturated magnetic amplifier, normally not employed because an objectionable high voltage is induced in the control winding. The simplicity of this circuit is helpful in gaining an understanding of the operation of more practical forms of the amplistat.

The load circuit of Figure 4 consists of an a-c supply voltage energizing the load through the rectifier and the output winding of the reactor. For steel mill applications, the a-c supply voltage will usually be less than 600 volts, single phase, having frequencies of 60, 50, or 25 cycles.

The control circuit of Figure 4 consists of a separate winding on the same core which is usually energized from a d-c voltage signal such as the drop across a resistor, a shunt, or the output of a tachometer generator.

Reference to Figure 5 is also necessary to understand the part that saturation of the reactor core plays in the operation of the amplistat. In normal amplistat design, the relation between the rate of increase of the a-c supply voltage and the rate of increase of flux density in the core is made such that saturation is reached at approximately the positive peak of the supply voltage with no applied control signal.

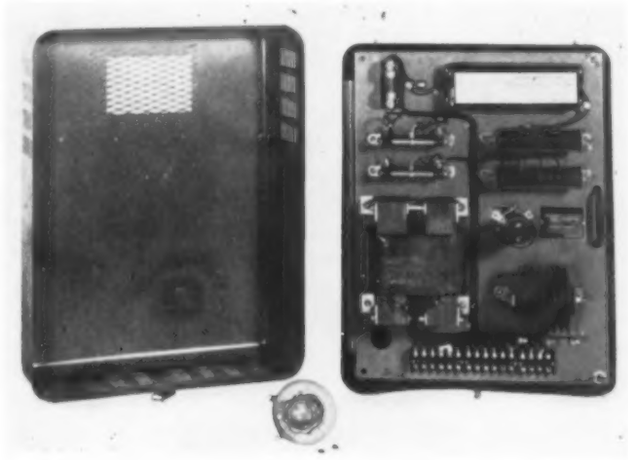
With *zero signal* applied to the control winding, the core saturates during the first half cycle of the impressed a-c voltage. Before this point is reached, there is a voltage induced in the output winding of the reactor which opposes the flow of current. Also the impedance of this winding is relatively large before the core saturates. When the core saturates, the flux no longer changes and there is no voltage induced in the output winding of the reactor, with the result that the impedance of the output winding drops to its resistance value and a large current flows through the rectifier and the load, super-saturating the core.

When a *positive signal* is impressed on the control winding so that the core is partially excited by this winding, if only to a small degree, the reactor core saturates sooner than with no excitation from the control winding, with the result that a large current flows through the rectifier and the load, for a greater portion of the positive half of the a-c voltage cycle.

When a *negative signal* is applied to the control winding, opposing the load circuit ampere-turns, the core saturates later than with zero signal to the control winding. Reference to Figure 5 shows that the core actually saturates after the peak value of the a-c supply voltage is reached. This explanation for this phenomenon is that, as in any highly inductive circuit, the magnetizing current and the flux it produces lags the applied a-c voltage by almost 90 electrical degrees. Therefore, the magnetizing current continues to increase, even as the applied voltage decreases. The magnetizing current attains the saturation value after the voltage peak has been reached. Therefore, with a negative signal the rectifier passes a large current through the load for a smaller portion of the positive half of the a-c voltage cycle than when zero or positive value of d-c signal voltage is applied to the control winding.

It follows that the magnitude of the negative signal impressed on the control winding can be increased to the point where the core will never saturate and the

Figure 3 — This packaged amplistat voltage regulator system was built for a high frequency generator.



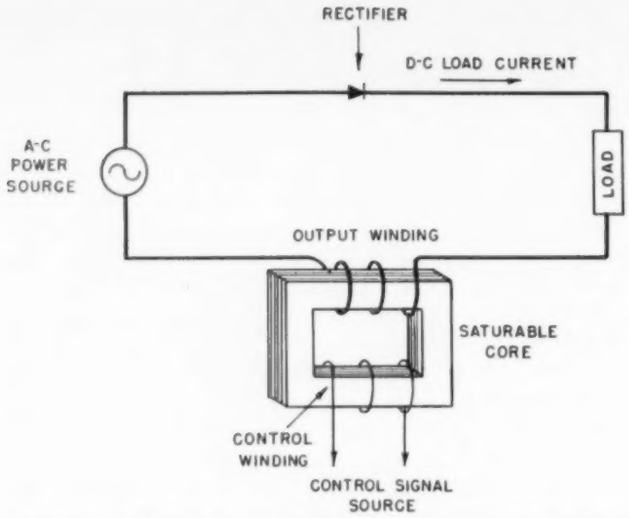
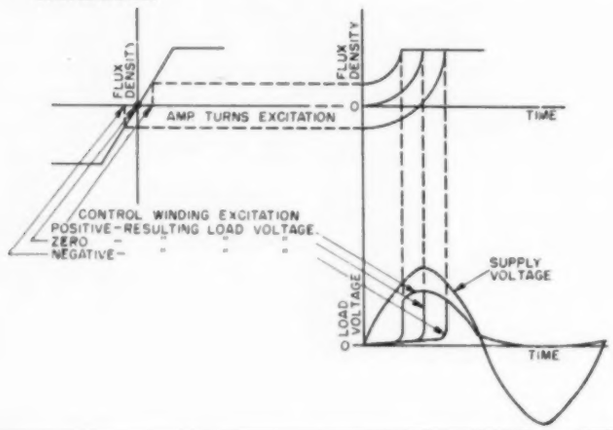


Figure 4 — Circuit of elementary, self-saturated magnetic amplifier.

Figure 5 — Core magnetization curve, with effects on flux density and load voltage for various control winding excitations.



amplistat conducts only a very small current through the load.

It should be noted that the output or load current is of pulsating nature. The wave form resulting from fractional half wave rectification requires that the effect of both the average value and the root-mean-square value of the output or load current always be considered. When the load is an exciting winding of a generator, another reactor, or a rotating regulator, for example, it is the average value of this current that is important in determining the average flux excitation, whereas the root-mean-square value must be considered when determining the heating in the excited winding, or in a load resistor.

During the negative part of the impressed a-c voltage wave, the current through the load and the rectifier is practically zero, but not exactly so. In fact, it actually reverses during part of the negative half cycle. When rectifiers are conservatively applied, the average current that flows through the load during the negative half of the a-c impressed voltage is less than 1 per cent of the maximum average value of output current of the amplistat.

The magnetization curve of Figure 5 is, of course, truly not an exact magnetization curve since the effect of hysteresis is not shown. Hysteresis causes a residual flux to remain in the core, as the flux is decreased from its saturated value to the point of zero excitation in both windings. However, the current in the output winding during part of the negative half cycle of the impressed a-c voltage does actually reverse slightly, providing a suiciding effect in disposing of the residual flux. In this way the core magnetization does not build up due to effect of hysteresis.

Like rotating regulators, amplistats can be equipped with several control windings. Independently varying signals impressed on each control winding are combined by the amplistat in their proper phase-magnitude relationship.

Unlike the rotating regulator, the amplistat is a single stage amplifier. Some applications requiring only one rotating regulator, which is a two stage amplifier, may require two amplistats in cascade connection for two-stage amplification.

COMMON AMPLISTAT CIRCUITS

The circuit shown in Figure 4 for an elementary self-saturated, magnetic amplifier has two operational disadvantages which practically eliminate the use of this circuit in amplistat design. First, a voltage of considerable magnitude at supply frequency is induced in the control winding by transformer action. This high induced voltage causes objectionable circulating currents to flow through the control source, which is usually of low impedance. Second, since only one rectifier is employed in the circuit of Figure 4, the current through the load pulses once during each cycle of the impressed a-c supply voltage. This limits the speed of response and also gives load currents of relatively low average value.

To overcome the above disadvantages, amplistats usually employ circuits, some of the more common of which are shown in Figures 6 through 10 inclusive. These circuits are characterized by the use of double core reactors bound together by one or more common control windings. This arrangement minimizes the induced voltage effects in the control windings encountered with the circuit of Figure 4. By the use of two cores bound with common control windings, phase relationship between the fluxes in the two cores is such that the net flux change at supply frequency through the control windings is minimized, greatly reducing the induced voltage in the control windings.

The circuits of Figures 6 through 10 are also characterized by the use of full wave rectifier circuits for single phase supply or by the use of multi-phase rectifier circuits. Full wave rectification is thus obtained with a ripple frequency in the load current equal to twice the frequency of the a-c supply voltage for single phase circuits. This results in improved speed of response and higher average load current.

The circuits of Figures 6 through 10 inclusive are certainly not the only ones which can be employed in amplistat designs, but are the ones most commonly used. Basically, the circuits combine familiar rectifier converter circuits with the use of one or more saturable core reactors.

Figures 6a and 6b are intended to show the same circuits, but Figure 6a shows clearly the core arrange-

ment which has been omitted from Figure 6b. Conventionally, amplistat circuits are drawn without regard to the core arrangement, which is taken for granted. The circuits of Figures 7 through 10 inclusive follow conventional practice by omitting core arrangement.

The single phase bridge circuit of Figures 6a and 6b is frequently used in systems requiring only a unidirectional output current. This circuit is usually the first to be investigated and evaluated against the requirements of the application.

The advantages of this circuit are:

1. Does not require a transformer, when electrical isolation of the load from the a-c power source is not necessary.
2. Operates well with either resistive or inductive loads.
3. Does not require an extra commutating rectifier for inductive loads.

The disadvantages of this circuit are:

1. Provides uni-directional output current only.
2. Uses more rectifiers than some other commonly used circuits.
3. Does not isolate the load from the a-c power source, as is sometimes necessary.

The single phase center tap circuit of Figure 7 can be used to advantage for resistive and slightly inductive loads. Combinations of this circuit are used in reversing center tap amplistat circuits for obtaining reversing output current.

The advantages of this circuit are:

1. Isolates d-c load from a-c power supply.
2. Provides a grounding point advantageous from a safety standpoint.

The disadvantages of this circuit are:

1. Provides uni-directional output current only.
2. Requires a transformer to obtain the center tap. The transformer must be over-sized because of rather poor wave form of current in primary and secondary windings.
3. Requires a commutating rectifier for highly inductive loads to provide a discharge path for the energy stored in the inductive load, while the supply voltage is going through zero. Without this commutating rectifier, the self-induced voltage in the load prevents the flux in the saturable core reactor from collapsing, thus damaging the performance of the amplistat.

Figure 8 shows a single phase voltage doubler circuit which is a special purpose circuit used to supply high impedance loads to obtain current amplification factors as much as a thousand times those obtainable with the bridge or center tap circuits. The speed of response of this circuit is comparable to that of the other common circuits, despite the higher amplification factors obtained. High amplification factors result from resonance between the a-c windings and the capacitors.

The advantages of this circuit are:

1. High amplification factors.
2. Operates well with either resistive or inductive loads.
3. Does not require an extra commutating rectifier for inductive loads.

The disadvantages of this circuit are:

1. Provides uni-directional output current only.
2. Very sensitive to slight variations in a-c supply voltage and frequency, which should be very constant for this circuit.
3. Requires extra components in the form of capacitors.
4. Does not isolate the load from the a-c power supply.

Figure 9 shows a single phase, reversing, center tap circuit. Many applications, such as adjustable speed reversing drives, require that the output current of the amplifier, supplying excitation to the generator, be varied from zero to maximum in both positive and negative directions. Figure 9 shows an amplistat circuit which can be used for applications of this type.

In the circuit of Figure 9 a pair of center tap amplistat circuits are used in combination with a common transformer. The output current from each center tap circuit is passed through a generator shunt field. For this circuit the generator must be equipped with two shunt fields, each capable of exciting the generator to rated voltage output.

With zero signal impressed on the control winding, the current through each generator field is equal, but in opposite directions, so that the resultant net output or generator excitation is zero.

With maximum positive or maximum negative signals impressed on the control winding, the proper shunt field of the generator has maximum excitation, while the other opposing generator shunt field has minimum excitation. In this way, the voltage of the generator can be made maximum in either direction.

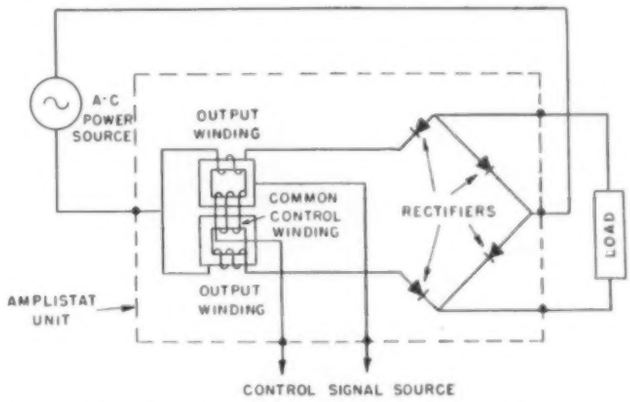
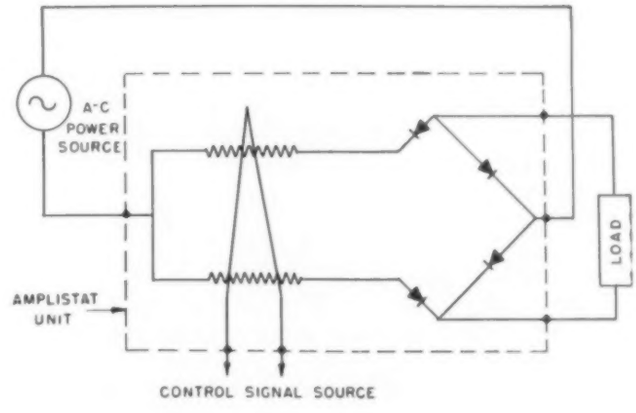


Figure 6A — Amplistat using single phase bridge circuit showing core arrangement.

Figure 6B — Typical schematic diagram of amplistat using single phase bridge circuit ignoring core arrangement.



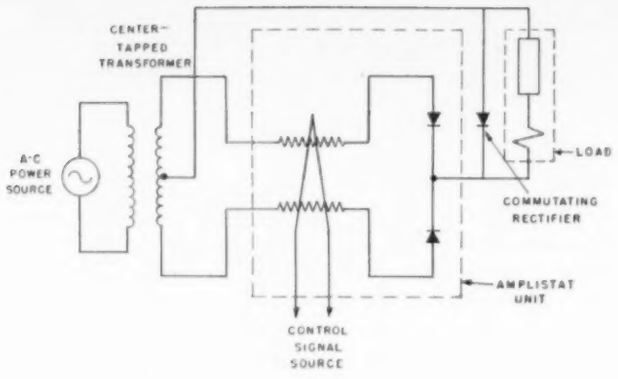


Figure 7 — Amplistat using single phase center tap circuit and commutating rectifier for inductive load.

In a more general adaptation of the circuit of Figure 9, the generator shunt fields are replaced with IR drop resistors and the load connected across these resistors at points A and B. The load receives a voltage equal to the difference in IR drop across each of the resistors. In the same manner as previously described for the generator fields, the voltage impressed on the load is zero for zero signal impressed on the control winding or maximum in either the positive or negative directions for corresponding maximum signal voltages impressed on the control windings.

The advantages of this circuit are:

1. Provides output current in both directions.
2. The net output of this circuit is affected much less by variations in a-c voltage and frequency than any of the other circuits described in this article. This feature makes this circuit very useful as the first stage of a multi-stage amplifier.
3. Isolates d-c load from the a-c power supply.
4. Provides a grounding point advantageous from a safety standpoint.

The disadvantages of this circuit are:

1. Requires a transformer to obtain the center tap.
2. Requires commutating rectifiers.
3. When IR drop resistors are used instead of direct application of the amplistat output to generator fields, considerable power is lost in the resistors, detracting substantially from the efficiency of the amplistat unit.

In general, required current outputs can be obtained more economically with fewer components using single phase amplistat circuits rather than multi-phase circuits. In rare cases, particularly for frequencies of a-c voltage supply as low as 25 cycles, when the maximum possible speed of response is desired, multi-phase amplistat circuits sometimes are economically justifiable. Figure 10 shows the elementary connections for the three phase wye circuit, which is just one of many that can be employed.

The advantages of this circuit are:

1. Improvements in the maximum possible speed of response over single phase circuits.
2. Improved form factors of the output current over single phase circuits, such that the average current value is more nearly equal to the rms current value.
3. Isolates d-c load from the a-c power supply.
4. Provides a grounding point advantageous from a safety standpoint.

The disadvantages of this circuit are:

1. Provides uni-directional output current only.
2. Requires a transformer to obtain the wye point.
3. Requires commutating rectifiers for inductive loads.
4. Requires more components at somewhat higher cost than single phase circuits of equivalent output.

AMPLISTAT CHARACTERISTICS

Certain characteristics of the amplistat are of vital importance in understanding the operation, application,

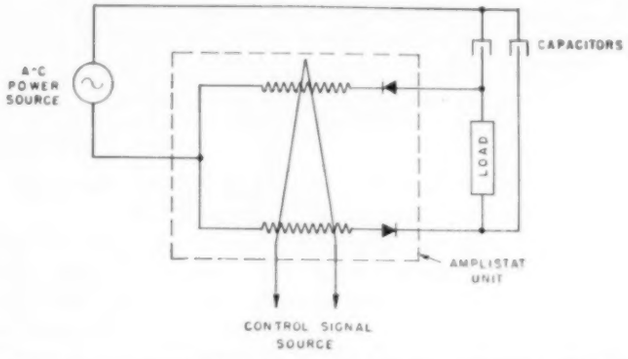


Figure 8 — Amplistat using single phase voltage doubler circuit.

and performance of amplistat regulating circuits. Although detailed design characteristics necessary for proper proportioning of cores and windings are beyond the scope of this paper, the following will be of interest to steel mill engineers.

Input-output characteristic — The steady-state relation between average output current and average input current is shown in Figure 11. This is the characteristic for an amplistat connected to a load of optimum resistance. It is called a steady-state characteristic because it does not show that a change in output current corresponding to a change in input current will be attained only after a time delay. This time delay is caused by the effect of inductance in the input and output circuits, designed to be as small as possible, for high speed of response.

The normal regulating range of an amplistat is selected to be that portion of the input-output characteristic through which the average load current varies sharply and almost linearly with changes in control signals. It is in this range that the greatest amplification factors are obtained. Under conditions of large transients, such as heavy loads during acceleration of a drive, the amplistat may be forced into its non-linear output region, providing its maximum limit of forcing to the regulating system.

It should be noted that the steady-state input-output characteristic shows an increase in output current for excessively large values of negative signal current in excess of the negative signal currents required for normal amplistat operation. This increase in output current is caused by the core being saturated by the signal current itself. Closed cycle regulating systems are usu-

ally designed so that an increasing negative signal normally produces a degenerative effect. If instead an increasing negative signal produces a regenerative or cumulative effect, a condition of instability exists.

This condition of instability for an increasing negative signal is an abnormal one not usually encountered in amplistat applications. When encountered, methods are well known for avoiding it.

Speed of response — No definition for speed of response of an amplistat has been universally accepted. However, it can be defined as the time required for the load current to build up to 63 per cent of its final average value with a suddenly applied control signal as obtained by closing a switch from a battery source. This definition of speed of response requires a pure resistance load to avoid the effect of the time constant of an inductive load.

With a pure resistance load, the speed of response of the output circuit can be considered as being practically instantaneous. Therefore, by far the greater part of the time required to build up the load current after a suddenly applied control signal is due to the time delay in the control winding circuit.

The speed of response of the control circuit can be controlled by the proper proportioning of the inductance-to-resistance ratio. With a large inductance and low circuit resistance, the speed of response will be low, but the overall amplification of the amplistat will be great. With a low ratio of inductance-to-resistance, the speed of response of the control winding circuit will be high.

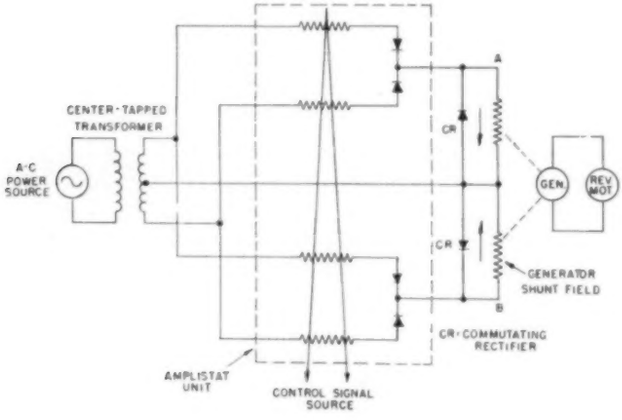


Figure 9 — Amplistat using reversing center tap circuit.

At the expense of overall amplification, the overall speed of response of the amplistat can be made very high, but not less than the time represented by one-half cycle of the a-c impressed voltage, if the average value of the output current is considered. Since the output current appears as pulses occurring once each half cycle, obviously a change in the average output current cannot be observed until the next pulse appears after the signal is applied to the control winding.

The oscillogram of Figure 12 shows somewhat obscurely test results on an amplistat supplying a resistance load. The oscillogram shows that the time required to build up the load current to approximately 5.5 average amperes (determined from first incomplete half cycle) from practically zero with a d-c signal suddenly applied to the control winding is 0.011 seconds, approximately two-thirds of a cycle of a 60 cycle timing wave.

Since the load current appears as pulses, there is a definite relationship between frequency and the maximum speed of response that can be realized. Low frequencies, such as 25 cycles, place a definite limitation on the maximum speed of response. For very high speed of response, high frequency power supply should be used.

Amplification factor — In general, amplification factor is the ratio of output divided by input. In the case of amplistats, great care must be exercised in talking about amplification factor, since the ratio of steady-state average current values, ratio of changes in average current, and ratio of changes in average volt-amperes result in widely differing numbers.

Reference to Figure 11 shows that with zero input to the amplistat control winding considerable output current is obtained. The amplification factor is infinity. Therefore, the use of steady-state output and input currents in determining the amplification factor results in numbers not significant.

If the amplification factor is defined as:

$$F_a = \frac{\text{Change in average output amperes}}{\text{Change in average input amperes}}$$

then amplification factors for a particular amplistat having a definite number of winding turns can be obtained which have some significance. Figure 13 shows a plot of this amplification factor F_a computed from the steady-state characteristic of Figure 11. Figure 13 is interesting from the standpoint of defining the rather narrow range of maximum amplification, which is the optimum operating range of the amplistat.

A definition of amplification factor which applies generally to all amplistats regardless of winding design is:

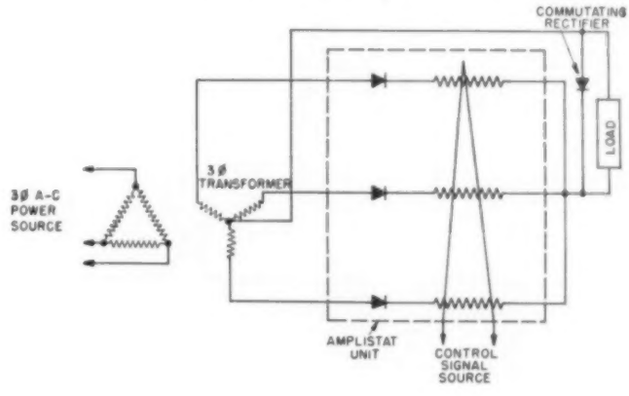
$$F_{va} = \frac{\text{change in average volt-amperes output}}{\text{change in average volt-amperes input}}, \text{ or}$$

$$F_{va} = \left(\frac{\text{change in average output amp}}{\text{change in average input amp}}\right)^2 \times \frac{\text{load circuit ohms}}{\text{control circuit ohms}}$$

This is the amplification factor actually used in the design of amplistats for a desired speed of response.

An approximate method for determining the resulting

Figure 10 — Amplistat using three phase wye circuit.



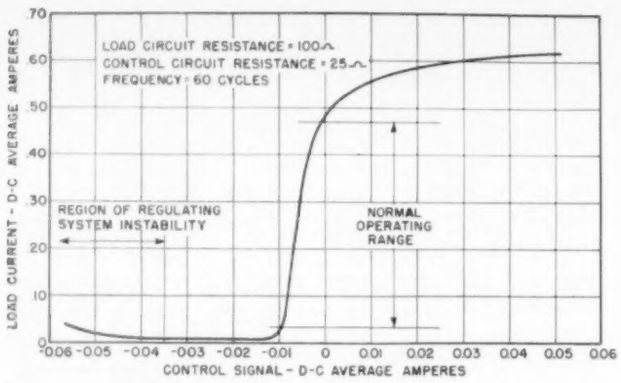

LOAD CIRCUIT RESISTANCE = 100Ω
CONTROL CIRCUIT RESISTANCE = 25Ω
FREQUENCY = 60 CYCLES
REGION OF REGULATING SYSTEM INSTABILITY
NORMAL OPERATING RANGE
LOAD CURRENT - D-C AVERAGE AMPERES
CONTROL SIGNAL - D-C AVERAGE AMPERES

Figure 11 — Typical input-output characteristic of an amplistat showing relation between load current output and control signal.

amplification factor for a given speed of response when taking into account a given type of core material is the following:

From curves like Figure 13 for a particular amplistat, the maximum value of current amplification factor can be obtained. This factor squared multiplied by the ratio of the load circuit to the control circuit resistance yields th maximum amplification factor F_{va}.

The following table lists approximate values of F_{va} obtained with amplistats using the core material indicated having a 1 second speed of response:

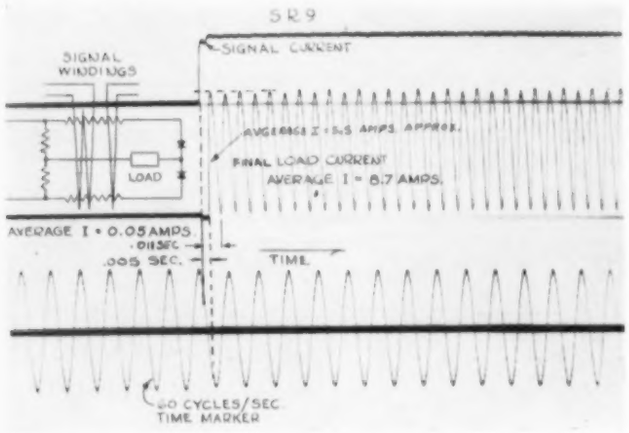
TABLE I

Core material	Amplification factor for 1 sec speed of response
XS10 — Grain oriented silicon steel	1,000,000
Nicalloy	700,000
MuMetal	300,000

The above table is based on optimum saturable core reactor design for 60-cycle operation.

The average volt-ampere amplification factor from the above table may be used for different power supply frequencies if multiplied by the ratio of the actual frequency to 60 cycles. For speeds of response less than one second, the amplification factors given in Table I

Figure 12 — Oscillogram shows speed of response of the output current of an amplistat for a d-c signal suddenly applied to a control winding.



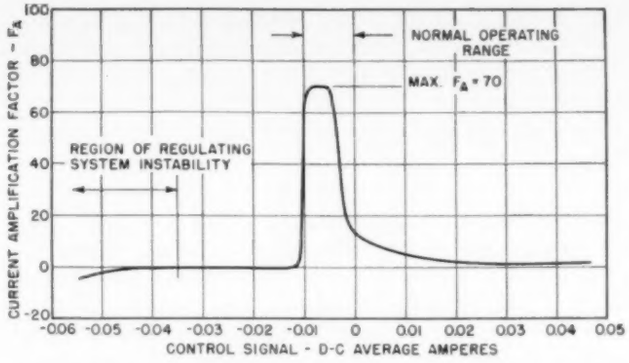

NORMAL OPERATING RANGE
MAX. F_a = 70
REGION OF REGULATING SYSTEM INSTABILITY
CURRENT AMPLIFICATION FACTOR - F_a
CONTROL SIGNAL - D-C AVERAGE AMPERES

Figure 13 — Typical characteristic of an amplistat showing relation between current amplification factor and control winding excitation.

must be decreased by the ratio of the desired speed of response to one second.

A numerical example showing how the approximate method outlined above can be used to determine the approximate maximum volt-ampere amplification factor and the speed of response for the particular amplistat of Figure 11 follows:

From Figure 13, Maximum $F_a = 70$

From Figure 11, the output circuit to input circuit resistance is: $\frac{100}{25} = 4$

$$\text{Maximum } F_{va} = (70)^2 \times 4 = 19{,}600$$

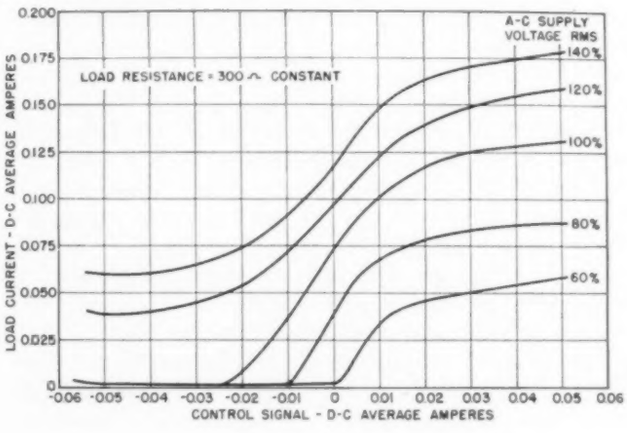
Knowing the amplification factor of a particular 60-cycle amplistat and its circuit and assuming SX-10 core material, the speed of response as defined in this paper is:

$$\text{Speed of response} = \frac{19{,}600}{1{,}000{,}000} = 0.0196 \text{ sec}$$

Characteristics of multi-stage amplistat amplifiers — Many applications require greater amplification than can be obtained in a single stage amplistat unit. Amplistats connected in cascade have overall amplification factors equalling the product of the amplification factors of the individual amplistats.

By proper design, the overall speed of response of a multi-stage amplistat can be made as high as the maximum speed of response of a single amplistat unit.

Figure 14 — Typical input-output characteristic of an amplistat showing relation between average load current and control winding excitation for various values of applied a-c voltage.



Effect of variations in a-c supply voltage and frequency — The effect of variations in the a-c supply voltage (which can be minimized by the use of constant voltage transformers) on the input-output characteristic of an amplistat is shown in Figure 14, for various per cent voltage values.

With more than 100 per cent voltage applied, the performance of the amplistat is affected as follows:

1. Optimum range of linear operation is decreased.
2. Amplification factor is decreased.
3. Maximum output current is increased.
4. Minimum possible current output is increased, tending to limit the output range of the regulating system.

With less than 100 per cent voltage applied, the operation of the amplistat is affected as follows:

1. Optimum range of linear operation is decreased.
2. Amplification factor is increased slightly.
3. Maximum output current is decreased.

For a given value of applied voltage, the effect of a decrease in frequency of power supply is the same as an increase in the applied voltage and vice versa.

Effect of variations in load resistance — Before the core of the amplistat reactor saturates, the effect of the load resistance in limiting the small load currents that normally flow is negligible compared to the impedance effect of the output winding. After the core saturates, the load resistance becomes the predominating factor in limiting the load current. The optimum load resistance is that which results in the greatest power transfer to the load for a given signal change.

The effects of changes in load resistance are shown in Figure 15. This curve shows that as the load resistance is decreased, the slope of the input-output characteristic is increased, signifying an increase in amplification factor. Maximum current output is also increased. As the load resistance is increased, the amplification factor and the maximum output current are decreased. The variation in load resistance for a constant supply voltage has practically no effect on the minimum possible current.

AMPLISTAT RATINGS

Amplistats are rated in average volt-amperes output. Since the output current is pulsating, and since the loads to which amplistats are commonly applied are excitation fields, practice indicates that the average value of the output current is of greater importance than the root-mean-square value.

If the output current of an amplistat supplying a pure resistance load is measured by an ammeter of the conventional D'Arsonval type, the meter reading is average amperes. If the current in the load is also measured by a hot wire or thermocouple type of ammeter measuring root-mean-square current, it will be found that the root-mean-square meter will read approximately 1.4 times the D'Arsonval ammeter. For inductive loads, this factor decreases because the inductive load will tend to smooth out the wave form of the output current.

In general, amplistat units are now built to operate without injurious heating in ambient temperatures not exceeding 40 C. The selenium rectifiers of amplistats should not be operated at temperature rises higher than 35 C above a 40 C ambient. When enclosures are furnished for amplistats, particularly in the larger sizes, the components must be de-rated as the heat radiating ability of the enclosure becomes the limiting factor.

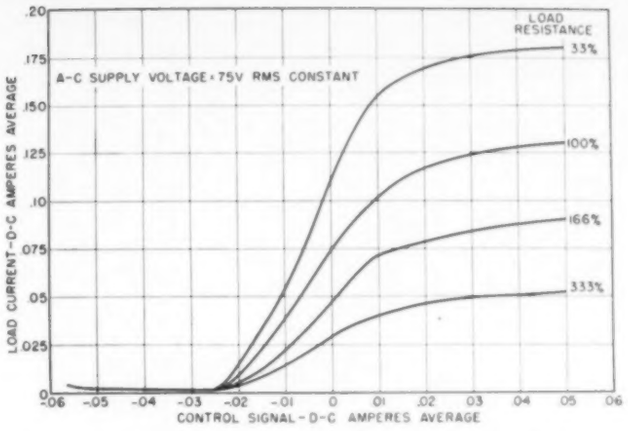


Figure 15 — Typical input-output characteristics of an amplistat showing relation between average load current and control winding excitation for various values of load resistance.

Amplistats have been built as large as 10,000 average volt-amperes and can be built even larger. Figure 1 shows an amplistat rated 1 average volt-ampere. This is one of the smallest amplistats in physical size that have been built. The range in amplistat ratings is great enough to meet the power requirements of most regulating systems.

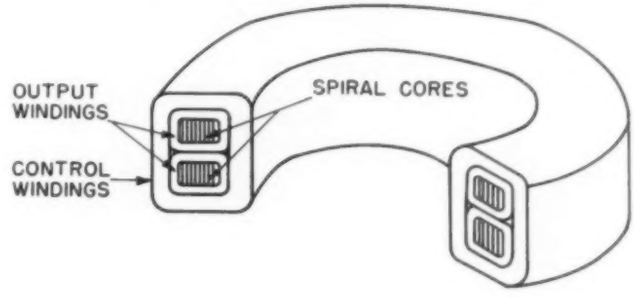
PHYSICAL FEATURES

Saturable core reactors of amplistats use two general core arrangements: punched type cores and spiral cores. The punched type core is employed on the reactors of the amplistat of Figure 2. The spiral core and its winding arrangement is shown on Figure 16. The spiral core is used when type SX-10 grain oriented silicon steel strip is employed. The higher amplification factors obtainable with grain oriented steel can be obtained only in cores of spiral form.

The space available for control windings is not a limitation with either the punched core or spiral core design. As many as six control fields of proper circuit constants have been employed without unduly affecting the size of the saturable core reactor.

The rectifiers used in amplistats are usually of the selenium dry plate type as shown in the amplistat of Figure 2. Germanium crystal rectifiers are employed for very small amplistat units, such as shown in Figure 1.

Figure 16 — Arrangement of output and control windings on a spiral core saturable reactor.



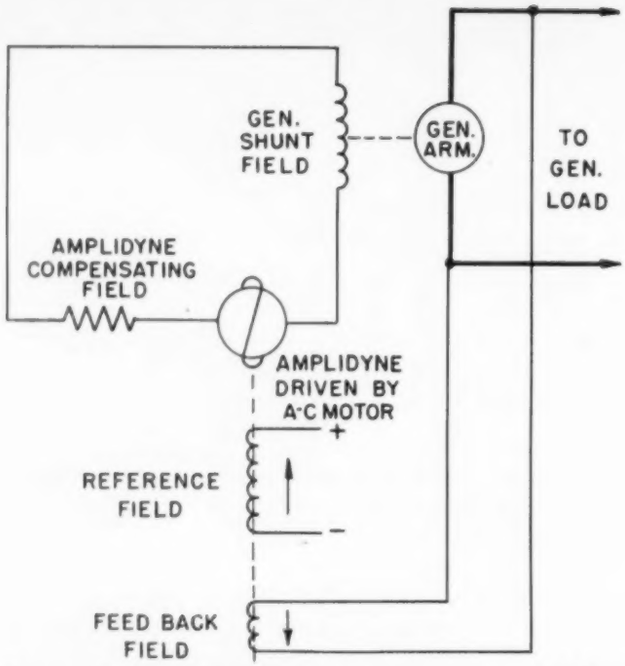


Figure 17 — Simplified circuit for a voltage regulating system for a d-c generator, employing rotating regulator amplifier.

AMPLISTAT APPLICATIONS

In order to establish a background for the understanding of amplistat applications, it should be helpful to compare the similarities and differences between equally simplified circuits for voltage regulating systems for a d-c generator using first the familiar and well known rotating regulator amplifier, and secondly, the relatively new amplistat amplifier.

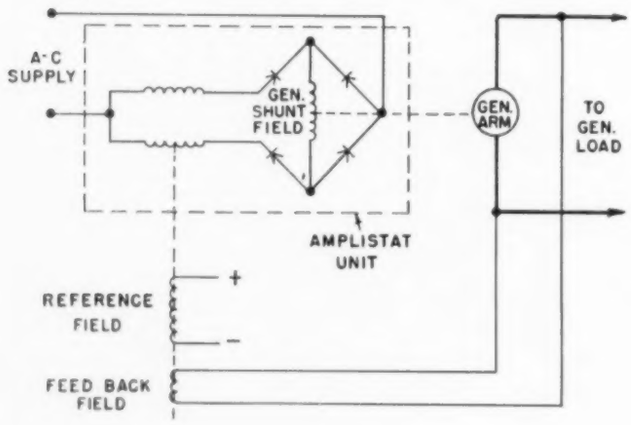
Figure 17 shows a simplified voltage regulating system using the well known amplidyne amplifier. This figure is taken from Mr. Mohler's paper "The Amplidyne — A New Tool of Many Uses," 1940 Proceedings, Association of Iron and Steel Engineers, p 460.

Figure 17 shows a reference field which is supplied from a constant voltage d-c exciting source. This reference field may supply as much as 20 times the normal excitation of the rotating regulator. With zero excitation in the feedback field, excitation of the rotating regulator from the reference field causes the amplidyne to build up to ceiling voltage. The circuit is designed so that with rated voltage from the rotating regulator the generator shunt field will be somewhat over-excited.

The feedback field of Figure 17 is connected across the generator armature and opposes the ampere turns of the reference field. When the voltage of the generator armature has attained its desired value, the feedback field will oppose the reference field excitation almost exactly — the slight difference in opposition is the normal excitation of the rotating regulator required to fully excite the main generator.

Figure 18 shows a circuit differing from Figure 17 mainly in that the main generator shunt field is supplied from an amplistat using the single phase bridge circuit. In this case the amplistat, like the rotating regulator, is equipped with a reference field capable of supplying many times the required net excitation of the amplistat. The feedback field must also be able to oppose the reference field almost fully. The difference in the net excitation between the reference and feedback fields is that value of ampere turns necessary to cause the amplistat core to saturate at the proper point of the a-c supply voltage wave, so that the average output current of the amplistat provides proper excitation to the generator.

Figure 18 — Simplified circuit for a voltage regulating system for a d-c generator employing an amplistat amplifier.



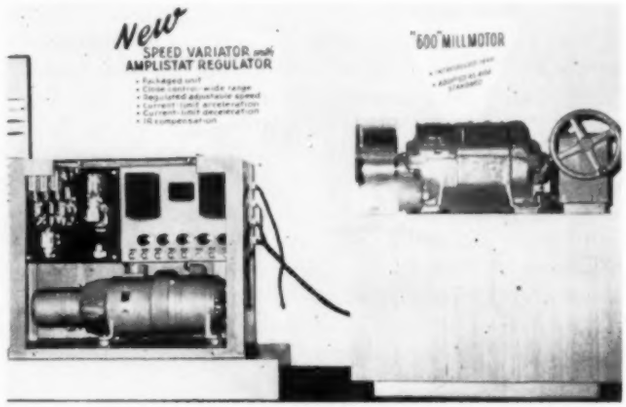


Figure 19 — View of a speed variator drive using amplistats shown at 1948 Iron and Steel Exposition at Cleveland, Ohio.

Since the excitation of the reference field is very great compared to the net excitation required to control the amplistat properly, a very slight change in the output voltage of the generator will cause a wide change in the output of the amplistat, resulting in good accuracy of regulation of the main generator voltage.

A point of difference between the two systems of Figures 17 and 18 is that the output of the rotating regulator is true direct current except for commutating ripple, while the output of the amplistat is of pulsating nature. Another point of difference is that the amplistat circuit is supplied with single phase a-c power, whereas the rotating regulator is usually driven by a three phase a-c motor.

ADJUSTABLE VOLTAGE SPEED VARIATOR DRIVE

At the 1948 AISE Exposition in Cleveland, our company exhibited a speed variator drive in actual

operation which employed self-saturated magnetic amplifiers or amplistats. Figure 19 is an actual photograph of the exhibit which has been retouched to use the word "amplistat" rather than the words "magnetic amplifier." Further, the magnetic amplifier components mounted on the panel are shown in the retouched photograph as boxes, these being the packaged amplistat units in their own enclosures.

Figure 20 is a block diagram of the circuit for the speed variator drive of Figure 19. The amplistat preamplifier is the small box shown between the two larger boxes on the panel of Figure 19. The amplistat power amplifier includes the two larger boxes on the panel.

The amplistat preamplifier employs the single phase bridge circuit of Figure 6. The two amplistat power amplifiers together with a center tap transformer, not shown in Figure 19, form a reversing center tap circuit almost exactly as shown in Figure 9.

The functions performed by the amplistat regulating system in this application are as follows:

1. Generator voltage is regulated through a wide range of pre-selected values.
2. Speed regulation is held to within plus or minus 2 per cent at top operating speed by a combination of generator voltage regulation modified by suitable IR drop compensation.
3. Current limit control of acceleration.
4. Current limit control of regenerative braking.
5. Equally regulated performance in either direction of motor rotation.

Speed variators using amplistat circuits are not yet in commercial production, but their overall performance can be equal to and in some minor respects more favorable than speed variator drives employing electronic amplifiers which are in commercial production.

VOLTAGE REGULATORS FOR POWER RECTIFIERS

Ignoring frequency changer applications, power rectifiers are used in steel mills to supply:

1. Constant potential buses, usually 250 or 600 volts d-c.
2. D-c motors, singly or in groups, with adjustable voltage power, forming an adjustable speed drive. A hot strip mill bus is a special case of this general application.

In either of these applications, a regulating system must be used, to regulate the rectifier output voltage to the desired constant or variable standard, despite changes in a-c impressed voltage, regulation in transformer and rectifiers, etc.

In ignitron type power rectifiers, the arc in the ignitron element must be fired for each half cycle of the impressed voltage by applying to the igniter tips a voltage impulse of steep wave front. The network system that supplies this voltage impulse is controlled by means of a group of saturable core reactors of the conventional type, that is reactors which have d-c voltage impressed on the control windings and whose output controls an a-c circuit. Changing the d-c voltage impressed on the control winding causes the ignitron element to be fired at the desired point of the a-c voltage wave.

The voltage regulator circuit for a constant potential

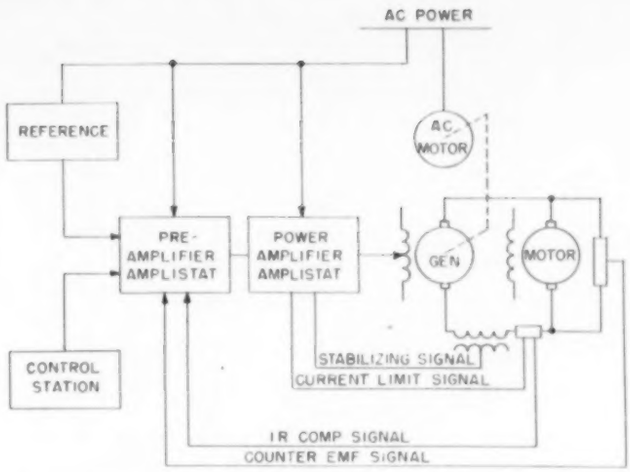


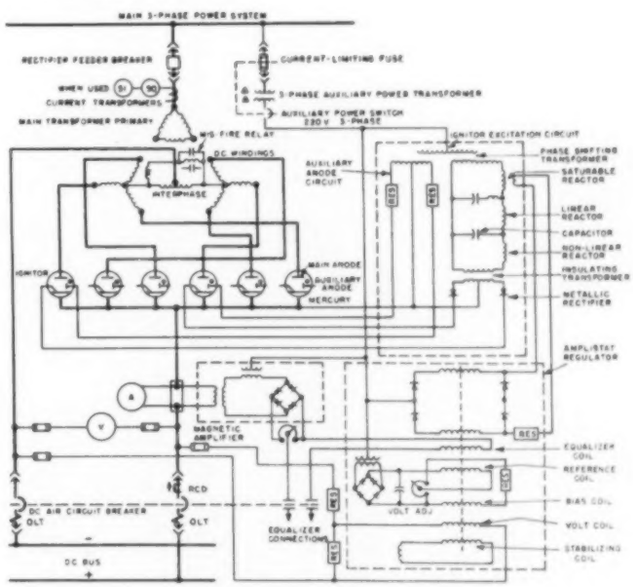
Figure 20 — Block diagram of the circuits for a speed variator drive using amplistats for voltage regulation and current limit control.

rectifier to supply a 250-volt mill bus is shown in Figure 21. The saturable reactor windings are supplied with direct current from an amplistat using the conventional single phase bridge circuit of Figure 6. Five control fields of the amplistat are employed for the following purposes:

1. A reference control field for providing an overabundance of amplistat excitation for high ceiling voltage.
2. A voltage control field which opposes the reference field in exciting the amplistat.
3. A bias control field which furnishes a small amount of negative excitation which can be adjusted to permit operation of the amplistat over its operating range of greatest amount of amplification.
4. A stabilizing or anti-hunt field.
5. An equalizing field not used with one rectifier, but used for cross-compounding to obtain desirable load division between two or more rectifiers.

Figure 22 shows an amplistat applied to the regulat-

Figure 21 — Schematic diagram of an amplistat voltage regulating system of a constant potential power rectifier.



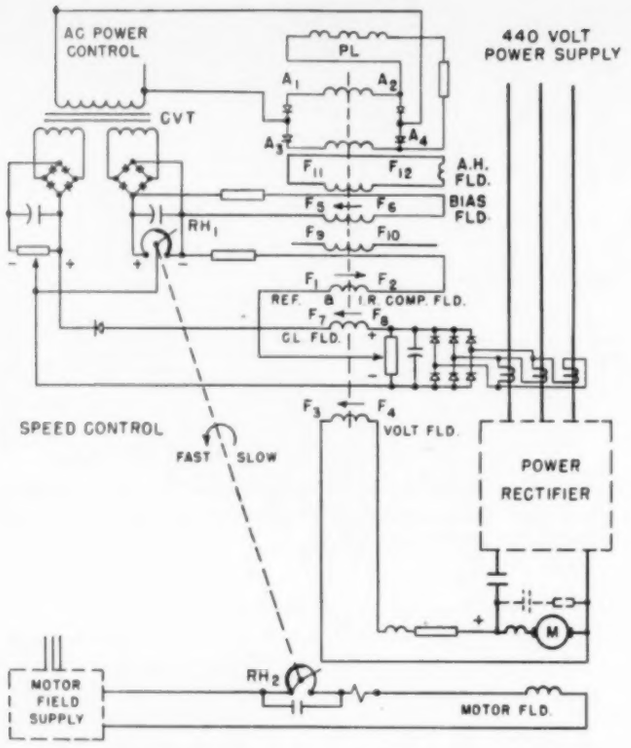


Figure 22 — Schematic diagram of amplistat voltage regulating system applied to an adjustable speed drive using a power rectifier.

ing system of an ignitron type rectifier for an adjustable speed drive. The speed of this drive is varied from zero to motor base speed by varying the output voltage of the rectifier as is done in a hot strip mill during starting, and above base speed by weakening the field of the motor.

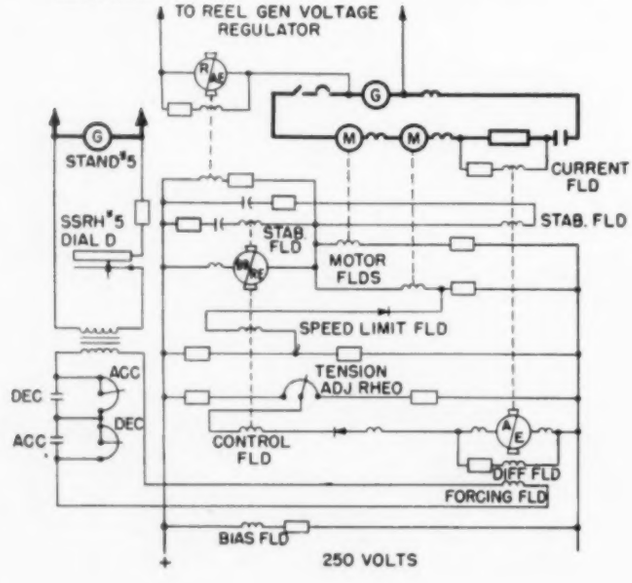
In this case, the standard of voltage regulation is now a variable quantity — namely, the variable voltage drop across the dial of a rheostat. The principal function of the amplistat regulator is to regulate the output voltage of the rectifier to be in strict accordance with this variable standard from zero to base speed of the motor. Other functions of the regulating system can best be understood by analyzing the purpose of the various control fields.

The amplistat of Figure 22 again employs the single phase bridge circuit of Figure 6 and is equipped with six fields, one a spare, of which five are used for the following purposes:

1. A reference field for providing an over-abundance of amplistat excitation for high ceiling voltage. The reference field is supplied not from a constant reference, but from the adjustable reference source provided by the dial of the rheostat. In an adjustable speed drive (not a hot strip mill), this reference is further modified so as to increase in magnetizing effect when the load current increases for IR drop compensation.
2. A voltage control field which opposes the reference field and which is supplied from the motor cemf or the bus voltage, causing this voltage to be maintained regardless of variation in a-c supply voltage or inherent rectifier regulation.
3. A current limit field which opposes the main reference field so as to reduce the voltage output of the rectifier when the output current exceeds a predetermined value. This can occur either during acceleration or during excessive overload. This feature is not included in the case of a rectifier supplying a hot strip mill bus because a motor operated rheostat controls the rate of acceleration.
4. A bias field, opposing the reference field, on which is impressed a small negative signal for adjusting of amplistat operation through its best operating range.
5. A stabilizing or anti-hunt field.

It should be noted that this system may include the feature of current limit acceleration, the rheostat being used solely for presetting the running speed. If a drive cannot be accelerated with pre-weakened motor field, a motor operated rheostat can be used to control the rate of acceleration through the voltage range with full field and then the rate of acceleration through the field weakening range.

Figure 23 — Rotating regulator type current-tension regulating system is used for winding reel of a tandem cold strip mill.



CURRENT-TENSION REGULATOR FOR THE WINDING REEL OF A 5-STAND TANDEM COLD STRIP MILL

It is common practice to regulate preset constant tension in the strip between the winding reel and the last stand of a tandem cold strip mill holding constant the current input to the winding reel motor armature by varying the motor excitation. Neglecting such factors as changes in friction, and motor losses, constant current input to the reel motor armature so regulated for a constant applied voltage and strip speed will result in constant strip tension as the coil builds up.

On the world's fastest 5-stand tandem cold strip mill located at the Jones & Laughlin Steel Corp., Aliquippa, Pa., our company originally furnished a current-tension regulator for the winding reel, using a rotating regulator type buck-boost regulating exciter and an amplidyne type amplifying exciter, the schematic circuit for which

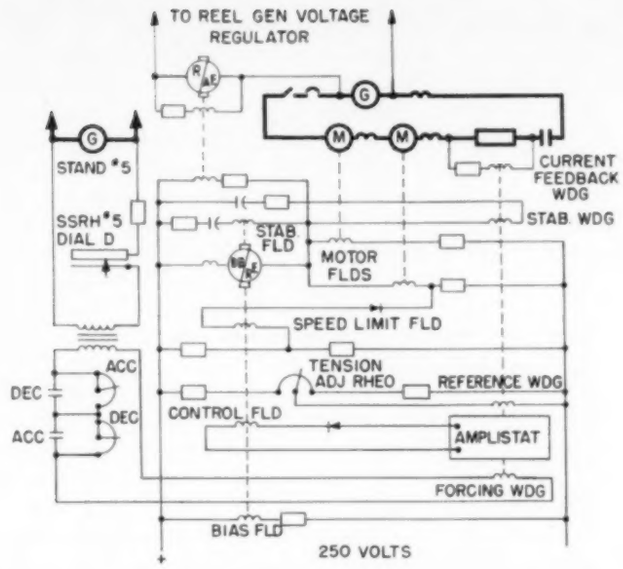


Figure 24 — Amplistat-amplidyne type current-tension regulating system used for winding reel of a tandem cold strip mill.

is shown in Figure 23. This system has operated for almost two years with excellent results.

With the full cooperation of the Jones & Laughlin Steel Corp., an amplistat unit for replacing and performing the same functions as the rotating regulator type amplifying exciter AE has been installed. The connections for the amplistat-amplidyne regulating system are shown in Figure 24. On this trial application, switches have been installed so that the connections can be changed quickly to permit ready comparison of performance with either the rotating regulator or amplistat amplifying unit.

The rotating regulator type amplifying exciter of Figure 23 serves the following purposes:

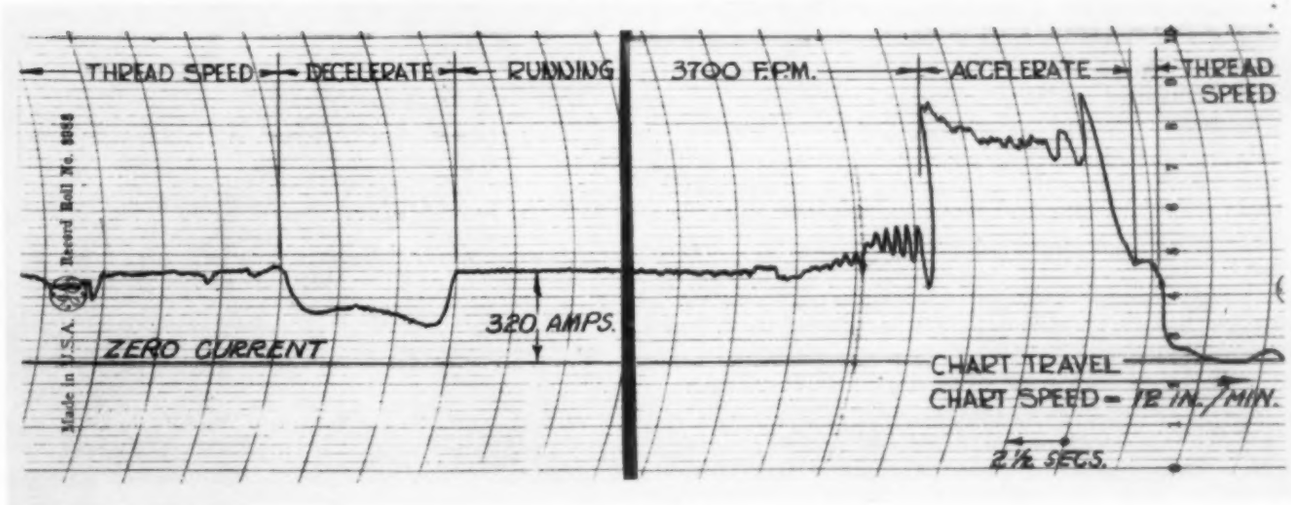
1. It amplifies the voltage drop from the armature current signalling resistor, permitting the use of a smaller resistor with less loss.
2. It amplifies materially the forcing signal during acceleration of the mill, which calls for an increase in the current input to the winding reel motor so as to provide additional torque for accelerating the inertia of the winding reel and motor armature.
3. It amplifies materially the forcing signal during deceleration of the mill which calls for a reduction in the current input to the winding reel armature to compensate for the overhauling torque produced by the energy stored in the winding reel, motor armature and coil.

In the circuit for the amplistat-amplidyne type regulator of Figure 24, the amplistat unit accomplishes the same functions as the amplidyne type amplifying exciter of Figure 23 except, in addition, the amplistat also does the regulating since its reference winding is excited from the fixed standard, which is the drop across the tension adjusting potentiometer. In this system, the BBRE exciter is simply an amplifier, whereas in the system of Figure 23 the rotating regulator type exciter BBRE is the regulating element since its control field is excited from the voltage difference between the rotating regulator amplifier AE and the drop across the tension adjusting potentiometer.

The performance of the amplistat-amplidyne regulating system of Figure 24 is shown on the ammeter chart of Figure 25, taken with a photoelectric recorder adjusted to be critically damped for a full scale change in 0.23 second. Reading from right to left, the chart shows first the input current to the winding reel motor armature during initial threading conditions when the wraps on the reel are few, then a considerable increase in the armature current during acceleration, with a decrease to 320 amperes as a running speed of 3700 fpm is reached. In order to reduce the length of the chart, the bulk of the coiling period has been cut out. As the mill decelerates to threading speed, the armature current is considerably reduced by the action of the amplistat amplifier. When deceleration is completed, the armature current is again established at the running value and held until the reel is stopped for removal of the coil.

The use of the amplistat in this application is motivated by a desire to substitute static devices for rotating devices, obtain slight improvement in regulating accuracy, if possible, and perhaps obtain some degree of simplification in similar regulating circuits. Since the amplistat unit has just recently been installed, it is too

Figure 25 — Photoelectric recording ammeter chart shows operation of amplistat amplifier in regulating winding reel motor armature current to meet requirements of constant strip tension.



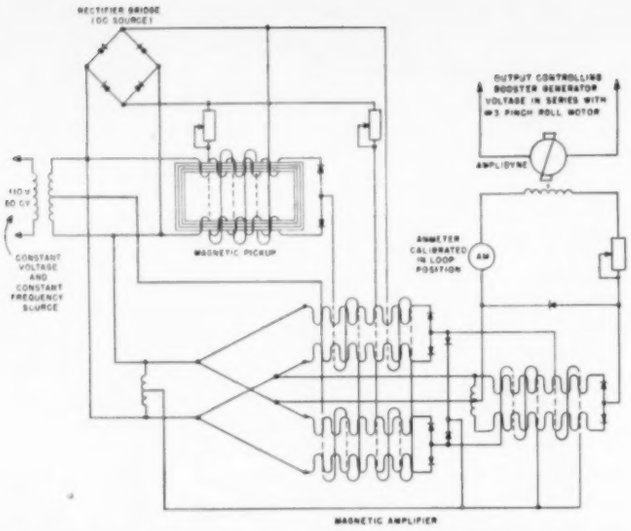


Figure 26 — Schematic circuit diagram of amplistat regulating system for control of strip catenary in a pickling tank.

early to go further in conclusion than to say that the amplistat unit gives promise of attaining the objectives set for it.

REGULATING SYSTEM FOR CONTROL OF STRIP CATENARY IN A PICKLING TANK

In the pickling of steel strip, the maximum efficiency is obtained when the strip footage in the catenary in the pickling tank is held constant and at a maximum value, without bruising the strip surface on the bottom of the pickling tank.

The length of the strip catenary has commonly been controlled by operating a rheostat controlling the field of one of the pinch roll motors or its booster generator from a dancer roll which rides on the strip on the catenary. This arrangement has been troublesome mechanically, and has left much to be desired in accuracy of catenary control.

A new catenary regulating system, in actual operation, shown schematically in Figure 26, uses a magnetic strip detector embedded in the bottom of the pickling tank. An amplistat amplifying system supplies the field of a rotating regulator exciter for the booster generator controlling the speed of one of the pinch roll motors. This system has proved to be a novel and an eminently successful solution of the problems encountered with the old dancer rheostat type of control.

The magnetic detector, specially constructed to resist the action of the acid, is placed in the bottom of the pickling tank. The output of the detector, which is varied by flux changes in the core due to slight changes in the proximity of the steel strip, is applied to one control winding of a reversing center tap amplistat unit (see Figure 9) which has a preference field, excited in opposition to the control field supplied from the magnetic detector. The output of this amplistat unit, however, is not sufficient to furnish the excitation requirements of the rotating regulator. This excitation is furnished by a second stage center tap amplistat (see Figure 7) which includes two control fields excited in opposition from the reversing center tap amplistat unit.

The physical appearance of the two-stage amplistat unit is shown in Figure 27, together with the two center tap auto-transformers. The large rectangular unit near the center is the compound filled, sealed reactor element for the second stage amplistat. The two smaller units are the compound filled, sealed reactor elements for the first stage amplistat. The cylindrical units are oil-immersed selenium rectifiers.

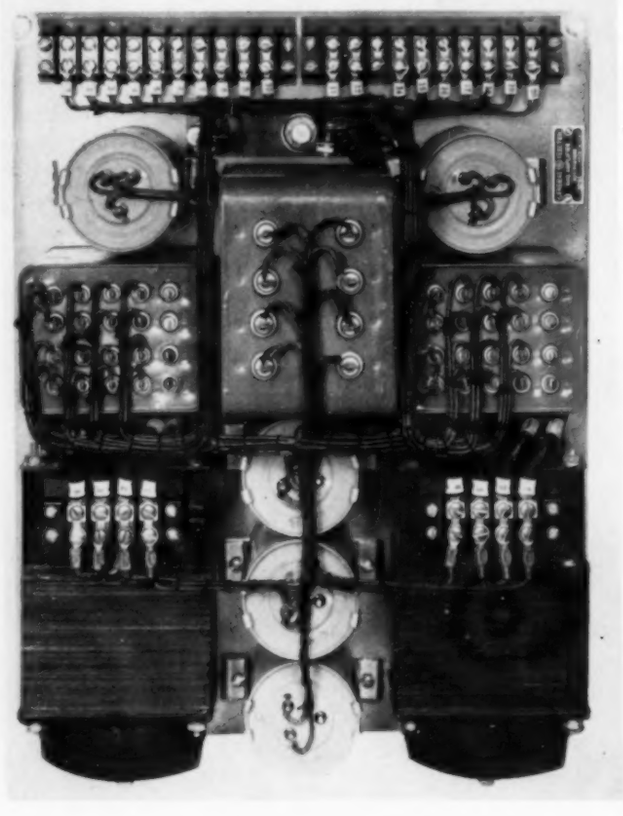
ADVANTAGES OF AMPLISTAT AMPLIFIERS

The applications of amplistat amplifiers just described and many others have been made because the advantages of the amplistat for these applications outweigh their disadvantages when compared with electronic or rotating regulator amplifiers.

Compared with electronic amplifiers, amplistat amplifiers have the following advantages:

1. Require no periodic maintenance — no tubes to replace.
2. Instantly operative — no warm-up time necessary.
3. More resistant to shock.
4. Can use control signals of lower voltage, as from a 50-mv shunt or a thermocouple.
5. Control windings of amplistats can be electrically isolated and yet the effect of several signal circuits can be composed, within the amplistat.
6. Cascading of stages of multi-stage amplistat amplifiers is easily accomplished because the output circuit is electrically isolated from the control

Figure 27 — Two-stage amplistat of regulating system for control of strip catenary in a pickling tank.



circuit. This is not true of electronic amplifiers.

Compared with rotating regulator amplifiers, amplistats have the following advantages:

1. Require no periodic maintenance since amplistats have no bearings, brushes, or commutators.
2. Cheaper to install since amplistats can be panel mounted and do not require floor space or conduits.
3. Eliminate starters and push buttons required for motors driving rotating regulator sets.
4. Are "tamper-proof" and dust-proof, when of sealed construction.
5. Regulating circuits using amplistats generally require smaller devices for system stabilization than circuits using rotating regulators.

DISADVANTAGES OF AMPLISTAT AMPLIFIERS

Amplistat amplifiers have some disadvantages and limitations which must be borne in mind when applying them. Some of these disadvantages are inherent in the device, while others may diminish in importance as actual operating experience is gained under steel mill conditions.

The disadvantages of the amplistat amplifiers when compared with electronic amplifiers are as follows:

1. Slower in speed of response for comparable amplification factors.
2. Signal power taken from the control source by electronic amplifiers can indeed be very small compared with that required for amplistats, although the amplistats can operate from most signal sources available in steel mill applications.

Compared with rotating regulator amplifiers, amplistat amplifiers have the following disadvantages:

1. Amplistats are inherently uni-directional in output. The rotating regulator can absorb power by regeneration — the amplistat cannot.
2. Since amplistats are only single stage amplifiers, it is sometimes necessary to use two amplistats in cascade to accomplish the same results as the two-stage rotating regulator, with consequent increase in cost disadvantage.
3. Amplistats are considerably more sensitive to changes in a-c supply voltage (unless constant potential transformers are employed) and frequency than rotating regulators driven by induction motors.

SUMMARY

Another tool is now available to help engineers of the iron and steel industry make better steel faster. It is a sturdy tool because its components are known to have long life. It is a versatile tool because it can be used in a wide variety of regulating systems. It is a simple tool requiring no periodic maintenance because it is a static device with no moving parts or electronic tubes.

Even the simplest tool must be well understood and its limitations appreciated before it can be used to the maximum benefit. With the background of understanding of regulating systems gained with electronic and rotating regulator amplifiers in the last 10 years, this knowledge will be acquired quickly.

The amplistat is not expected to revolutionize the iron and steel industry, but it will prove very useful in many applications. Together with electronic and rotating regulator amplifiers, it will soon establish its position as an active partner in the iron and steel business.

DISCUSSION

PRESENTED BY

R. T. LUCAS, Assistant Electrical Supt., Weirton Steel Co., Weirton, W. Va.

W. R. HARRIS, Manager, Metal Working Section, Westinghouse Electric Corp., East Pittsburgh, Pa.

H. E. LARSON, General Electric Co., Schenectady, N. Y.

R. T. Lucas: We have one of these magnetic amplifiers. It is located in our pickling line for the control of the strip height in the pickling tank, and I might say that it is doing a good job.

We have three methods for control of strip height, the amplistat, current control, and a looper roll. The roll is connected to the rheostat that controls the pinch roll motor. The looping roll caused some trouble due to deterioration of the roll due to acid, and, so far, the magnetic amplifier has done a very nice job. We have to please the operators, and they are very well satisfied with it.

W. R. Harris: The authors are to be commended on their very complete paper on the magnetic amplifier. As stated in the paper, development of this type of device in this country has been behind the development in Europe, principally by German and Swedish engineers. The reason for this is that American engineers have spent more time on the development and application of rotating regulators which have reached a high state of perfection. The Swedish have applied magnetic amplifiers to a large number of commercial equipments. The Germans used magnetic amplifiers extensively in military applications. Developments in this country during the past two years has been aimed at bringing us up-to-date on the device and its application.

The magnetic amplifier can be used as a regulating device and will probably find extensive use in the following fields:

1. To replace vacuum tube amplifiers where shock-proof construction and low maintenance are of paramount importance.
2. Used in conjunction with rotating regulators.
3. Used alone as a regulator or control device for small and medium power.

The device should not be thought of as a cure-all for replacing all existing regulators, but merely as a new tool which is to be added to the control engineer's repertoire.

The magnetic amplifier's most familiar counterpart in this country is the saturable reactor which has been used extensively on lighting control, measurements of very large direct currents, reactor type crane control, as a plating and reflow control element on tinning lines, and on automatic electric furnace controls. In more recent applications, the device has been developed and

refined, principally in circuiting and by use of new core materials, for use as a closed cycle rather than an open cycle control or regulating system. As stated in the paper, the magnetic amplifier can be used with circuit arrangements very similar to that in present use on rotating regulators.

The following applications of magnetic amplifiers have been made in recent months.

1. Servo-mechanisms and other control devices for military applications.
2. Tension control on a reel drive where the magnetic amplifier is used to directly excite the field of a 15-hp motor.
3. Voltage regulation on battery charging equipments, which application has been standard for several years.
4. Voltage regulation of large a-c generators in conjunction with rotating regulators.
5. On a d-c to a-c motor-generator set the device is used as a speed control unit on the d-c motors and as a voltage regulating unit on the d-c generator.
6. Speed control of d-c motors with the main power supply by dry type rectifiers. These are small machines for machine tool applications.

The name "amplistat" has not been standardized for all magnetic amplifiers, although the paper might give that impression.

Member: I should like to know whether there were any particular reasons why the larger amplistats use selenium rectifiers in preference to copper oxide.

H. E. Larson: The answer to this question is that copper oxide rectifiers are usually not used because the leakages with copper oxide rectifiers are greater than with selenium, and the losses somewhat greater. Also, copper oxide stacks in general are more bulky and heavier than selenium stacks of the same rating and can be justified only for low voltage applications. They can be used, but usually are not used.

Tentative List of Papers Scheduled for AISE Annual Convention

CLEVELAND PUBLIC AUDITORIUM, CLEVELAND, OHIO **SEPTEMBER 26, 27, 28, 29, 1950**

The Use of the Jet Mill for Combustion Purposes and for the Fine Grinding of Various Materials

Reduction of Hanging and Slipping in Blast Furnaces by Automatic Control

Electroplating Rectifiers

Preventive Maintenance of Electric Overhead Cranes

Low Inertia D-C Motors for Rolling Mill Drive

Graphite as a Lubricant

Extreme Pressure Lubricants

Laboratory Screening of All-Purpose Type Greases for Plant Performance Testing

The Design and Use of Tungsten Carbide Rolls for Cold Rolling Metals

The Continuous Seamless Pipe Mill

Rolling of Tool Steels

Transformer Oils in the Steel Plant

Requirements for a Modern Steel Mill Distribution System

Grounding Practice of the Inland Steel Co.

Supervisory Development

The Bethlehem Loop Course

Motor Inspection Training Program

What to Look for in Hydraulic Fluids

Rolling Solutions for Specialty Steels

Metal Drawing Lubricants for Wire, Tubing and Sheet Steel

The Public Demands Better Combustion

The Appliction of the Heat Prover to the Steel Industry

Economics of a 500-Ton Open Hearth Furnace

Oxygen for the Open Hearth — Its Storage and Distribution

Engineering and Purchases

Density Control of Coal Charged in Coke Ovens

The Use of a Fuel Oil as an Absorption Oil in Recovery of Light Oil from Coke Oven Gas

Blast Furnace Hearth Cooling

Temper Rolling with Modern Control

Temper Mill Power Requirements

Acceleration Characteristics of Tandem Cold Reduction Mills

Rolls for Centering and Alining Strip Materials

New Facilities for the Stocking and Shipping of Pipe at Lorain Works of National Tube Co.

Some Aspects of Selecting and Applying Gears for Rolling Mill Equipment

Analyzing Open Hearth Data — Statistics vs. Opinion

Turning and Peeling of Bars, Billets and Tubes

Television in Industry

EXPERIENCES IN OXYGEN FLOW MEASUREMENT

By CHARLES W. PARSONS
Assistant to the Vice President
Republic Flow Meters Co.
Chicago, Ill.

. . . . oxygen flow measurement presents special metering problems which have been satisfactorily solved in several plants . . . .

▲ OXYGEN is used to enrich the air to aid combustion and speed up the rate of melting down the scrap. Oxygen is supplied through a submerged lance to agitate the open hearth bath and reduce the carbon at a faster rate. Substantial quantities of oxygen are used in many steel mills for cutting scrap, cutting off billet hot tops, for automatic scarfing of blooms and billets, for hand scarfing of slabs and plates and for miscellaneous cutting operations. Experiments have been conducted on the advantages of enriching the blast to bessemer converters with oxygen, and on adding oxygen to the air being blown into blast furnaces.

Steel mills in different districts and individual mills in the same district have arrived at individual conclusions on their use of oxygen. Their reasons are most interesting and will be the subject of many other papers.

Oxygen is being used in such quantities and in so many mills that the measurement of its flow is established practice. These experiences in oxygen flow measurement have disclosed certain special metering problems, and have established a pattern for obtaining highest accuracy with maximum safety and minimum maintenance.

Just as all fuel flows are measured and all products are measured in modern mills and processes, these oxygen flows are measured. There are at least three reasons:

1. To know the cost of the oxygen used.
2. To show the operator the quantity being used.
3. To provide the records of amounts used which form the basis for improving the practice.

The cost of oxygen makes it prudent to measure the amounts purchased and the amounts distributed to each department, thus having accurate basis for purchase payment and for division of that cost among the departments and units using the oxygen. Figure 1 illustrates the simple tabulation of these oxygen meter readings and the charges made to the several departments of a Pennsylvania steel mill on the basis of these readings.

Oxygen is metered in at least five principal applications:

1. The amount, as purchased from tank car, trailer, or local oxygen generating plants, is paid for on the basis of that meter reading. Other bases of payment for large quantities of purchased oxygen have sometimes been found less accurate than proper metering. Figures 2 and 3 illustrate an unusually complete installation for metering the oxgyen purchased by one steel mill.
2. The flow to the principal departments of the steel plant is used as the basis of distributing the cost to the departments using oxygen. It is human nature for a department head to be sure that most of the oxygen is being used in other departments unless accurate meters show him exactly where it is used. Leaks and wasteful use of oxygen will be eliminated when each department is charged for its metered oxygen.
3. To measure flow to each open hearth furnace to enrich the flame and reduce the melt-down time. The mill installing individual oxygen flow meters on each of 24 open hearth furnaces, and the mill installing them

Figure 1 — Oxygen distribution to the different departments of a steel plant is given in this figure.

OXYGEN

Period 19

	Cubic Feet	
On Hand		
Incoming Meter		
Total		
On Hand		
Consumed		

Stand. Cost	Department	a/c Chg.	Cubic Feet	Amount	Cap. Dept. Expense
	Open Hearth #2 & #3	101-557			
	120" Mill Gas Cutting	112-557			
	206" Mill Gas Cutting (B.Fan)	122-557			
	Flangers	141-557			
	Nickel-Clad Conditioning 75%	153-557			
	Nickel-Clad Prepare 25%	158-557			
	Ingot Pack Welding	181-557			
	84" Steel Yard	230-557			
	120" Steel Yard (Conditioning)	231-557			
	206" Steel Yard (Conditioning)	232-557			
	Alloy Dept., Viaduct	234-557			
	Locomotive Shop	313-557			
	Machine Shop	362-557			
	Pipe Shop	366-557			
	Safety Shop	368-557			
	Misc. Weld Shop	377-557			
	General Maintenance	622-557			
	Armor Plate Plant	131-557			
	By-Prod. Shrade Ave.	841-557			
	Plant #1	891-557			
	Plant #1 (Loco. Frames)	891-557			
	Plant #1	911-557			
	Plant #2	911-557			
	Scrap Cutting	516-3331			
	TOTAL -				

Fuel Engineer

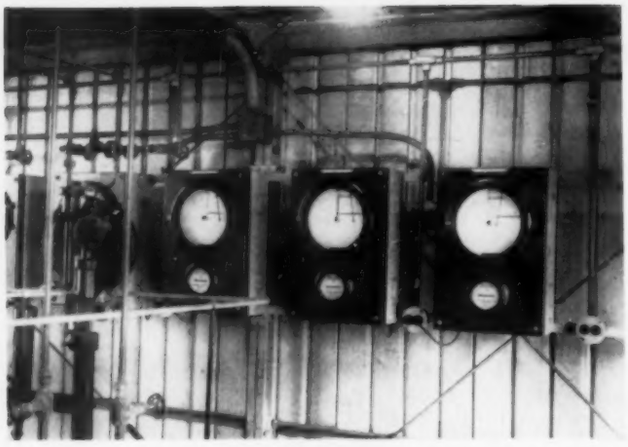


Figure 2 — Panels in a main meter house are shown in this figure.

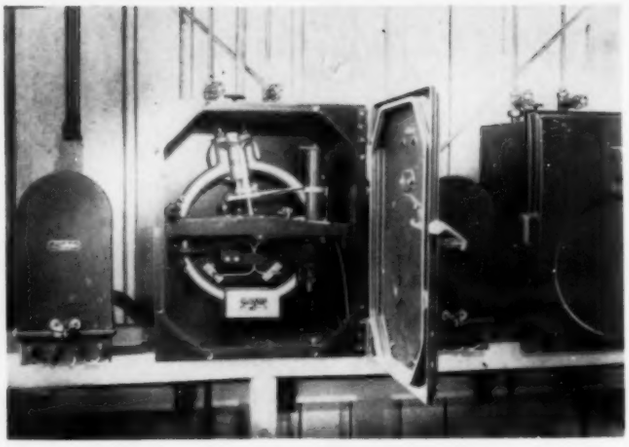


Figure 3 — Shown in this photograph are the compensators in the same meter house as is illustrated in Figure 2.

on 11 furnaces, and many others, believe that meters are essential to the proper use of oxygen. The first helper uses the meter indication to set the rate of oxygen flow to enrich the flame, and the meters' record of rate, time and total quantity is available as a guide to improve the next heat. Per cent of scrap used, practical charging rate, type of fuel, life of refractories, and value of shorter heats are among the factors determining whether to use oxygen.

4. When flow through lances into open hearth and electrical furnace baths is used to speed the reduction of carbon. The amount that it is necessary to reduce the carbon content of the bath to the desired content of the steel, plus some of the factors mentioned above, determine the economies of lancing. The oxygen meter gives the lance operator instantaneous indication of exactly how much oxygen is entering the bath and provides the flow record for comparison of results.

5. To measure rate and amount of oxygen used by hot scarfing machines and various cutting and hand scarfing operations. The several hot scarfing machines installed use such substantial quantities of oxygen for such very short periods, yet frequently, that its metering presents special problems. The charts of Figure 4 from the meter on the oxygen line to a hot scarfing machine illustrate the magnitude, brevity and frequency of these flows. The meter provides the information for regulating the rate of oxygen flow and the continuous check of that setting. Every steel mill has few or many scrap cutting operations with oxygen, some have hand scarfing of slabs, and some have extensive plate cutting operations. The metering problem in those cases is similar to, but less severe than on hot scarfing machines. Figure 5 is a chart from a meter on a line to such a varied use of oxygen.

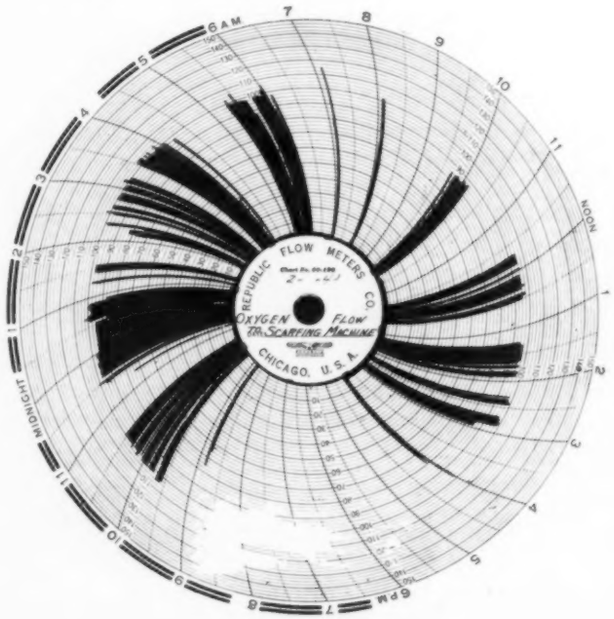
For these typical oxygen flow measuring problems there are many types and makes of meters. They can be grouped in six or more classes, and we will discuss them as groups.

1. Positive displacement meters are the standard for many gas and liquid uses, from the domestic water and gas meters up to the huge meters in industrial and utility gas pumping stations. Moderate sized meters of this general positive displacement type are used for oxygen measurement at point of purchase and for distribution flow measurement in a number of mills. The explosion hazard of grease accidently placed in a stuffing box makes the maintenance of such a meter an important responsibility. These meters have a mechanical integrator, but seldom are equipped with chart for providing records. This design has the moving parts of the meter in the oxygen line.

2. Mechanical float type orifice meters with recorder but no integrator are the simplest, lowest in cost, and most extensively used in gas measurement, and in many other oil field and industrial applications. The necessity for planimetering the charts to obtain the total flow makes the following type, with integrator, preferred by many industries. The problem of accurately measuring the very slight movement of the mercury with the mechanical float and its connected linkage raises a question of the accuracy at low flows. The contact of the oxygen with the mercury, and the need for a greaseless stuffing box, present additional problems in using this meter for oxygen.

3. This same mechanical float type orifice meter

Figure 4 — Chart shows flow of oxygen to a hot scarfing machine in a Chicago plant. The maximum flow is about 98,000 cfhr. Total of this chart in 24 hours is 171,000 cu ft. The duration of each flow was about 15 sec.



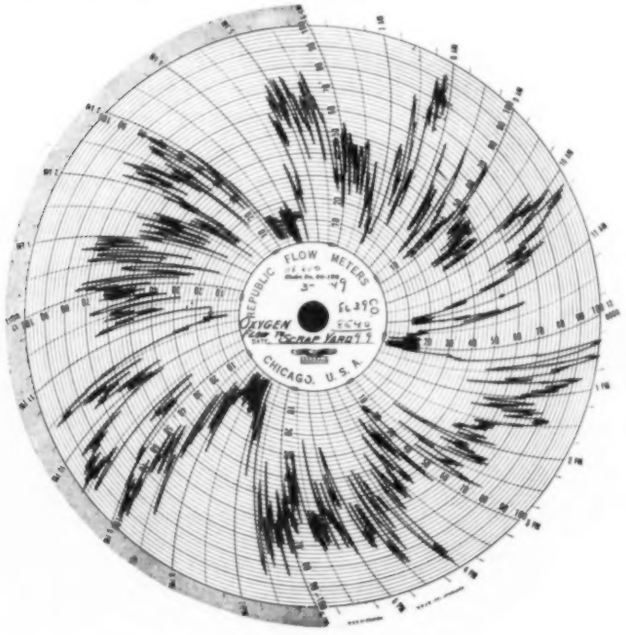
equipped with an integrator has the definite advantage of providing a total reading. The other features remain. Integrators are of two types, intermittent and continuous, and will be compared in the following discussion.

4. The ring balance orifice meter was first marketed in this country to handle dirty gases and it provides many improvements over the mechanical float type for totally containing the oxygen within the ring, such as the stuffing box is completely eliminated, along with its grease hazard. The mechanical ring balance meters available have the intermittent type integrator which measures the rate of flow only at intermittent intervals and accumulates a total sum from those periodic rates. Rapid changes in the rate of oxygen flow between these intervals would not be included in the total sum. The instruments of these meters are in the same case with the ring, and the piping extends from the instrument case to the pipe line.

5. The electric ring balance orifice meter provides two additional features not included in the mechanical type. The ring balance meter body may be located as near as desired to the orifice in the oxygen pipe line, as the instruments are entirely electric, and may be placed on the instrument panel and at any remote point. The electric transmission permits the use of the watt-hour type flow integrator. This is basically like every domestic electric meter and speeds up or slows down instantly to catch every change in the rate of flow. Figure 6 shows this watt-hour type continuous integrator. Its ability to catch the sudden changes in the oxygen flows to scarfing machines and other varying demands is appreciated by referring to the charts of Figure 4 and Figure 5. This Figure 5 chart is typical of oxygen flows for scrap preparation, hand scarfing, plate cutting, and the regular reversing of open hearth furnace firing and lancing.

6. Pneumatic-electric orifice meters confines the oxygen to a sylphon-sealed pneumatic transmitter and has an all electric transmission to remote indicator, recorder and watt-hour type continuous integrator to accurately totalize sudden large changes in flow. This wartime development, from an established combustion control master, provides special features particularly suitable for the measurement of oxygen and other special fluids.

Figure 5 — The chart shows the flow in a line to a scrap yard in the Cleveland district.



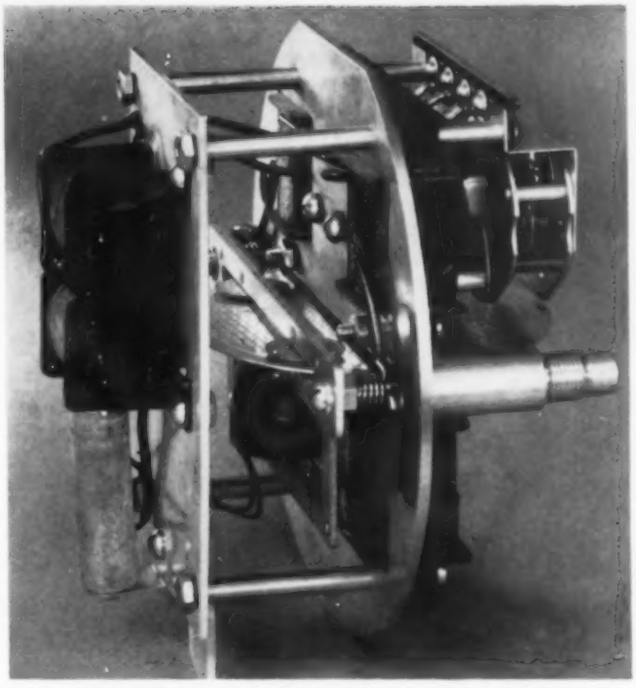


Figure 6 — Phantom view of a continuous watt-hour type integrator.

Some of the features of these several types of oxygen meters are illustrated in the accompanying diagrams and photographs and in the installation pictures.

Figure 7 is a section through a ring balance meter showing the ring which confines the oxygen, and which is turned on its ball bearing axis by the difference between the pressure ahead of the orifice in the oxygen line and the pressure after the orifice. The movement of the ring can operate a recorder manually, and an intermittent integrator can take readings at intervals to totalize those flow readings, as is done in mechanical ring balance meters.

The design illustrated here measures the turning of the ring electrically. The resistance coil, which is in series with the remote electrically operated instruments, is lowered as the ring turns clockwise. Each of the coil's approximately 100 steps terminates in a stainless steel rod of very accurate length. The ends of these rods are so spaced that the proper steps of the resistance coil are cut out of the circuit as these rods touch the surface of the mercury in the cup. By spacing the ends of the rods a few thousandths of an inch apart, the slightest movement of the ring, representing minute variations in the oxygen flow, are accurately measured electrically. The meter is easily set for zero reading, merely by the screw driver adjustment of the height of the mercury cup.

The instruments, being electrical, can be on the panel board on the charging floor or in a remote office, or can have an indicator for the operator and a record for

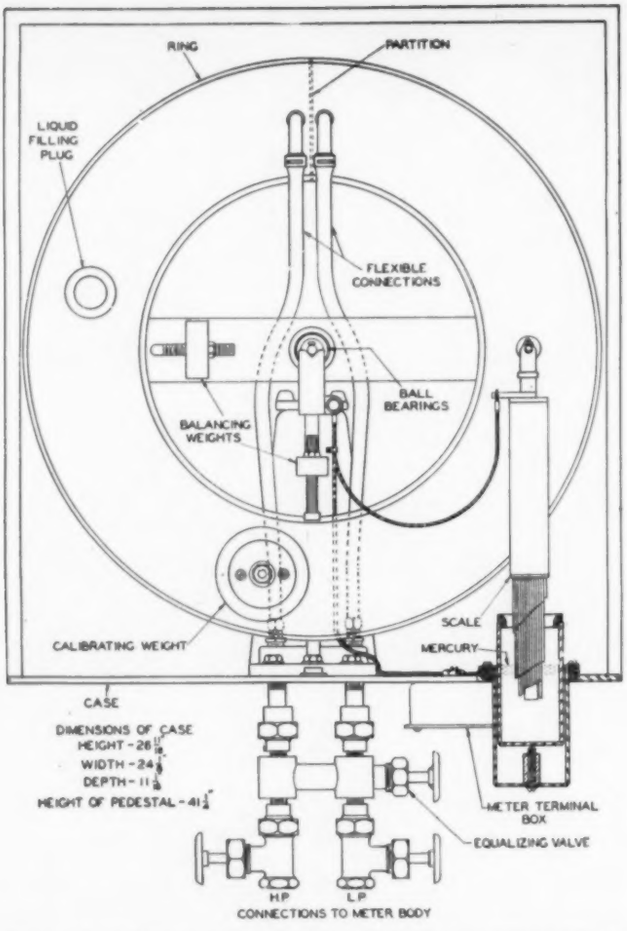


Figure 7 — Diagrammatic view of ring balance meter body showing ring, sealing fluid, scale and mercury well.

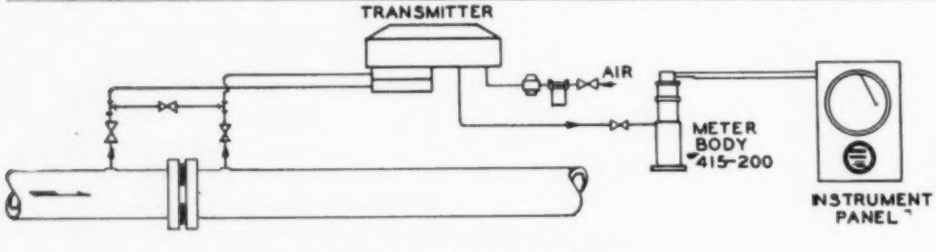
the fuel engineer. The integrator will be of the continuous count-up watt-hour type, so essential where variations occur in the rate of flow. Several installation photographs of this electric ring balance type of meter will be shown.

Figure 8 is a diagram of the pneumatic-electric orifice meter showing its three parts: pneumatic transmitter, electric transmitter and electric reading instruments. The pneumatic transmitter, shown in other illustrations, can be saddled on the oxygen line, or located near the orifice, to have minimum runs of oxygen piping. It uses a small amount of compressed air to transmit an impulse, exactly proportional to the oxygen flow differential being measured. This air impulse raises the mercury in the U-tube of the electrical transmitter accurately proportional to the oxygen flow differential. This rise of mercury is measured by its touching the ends of the stainless steel contact rods, thus shorting out the corresponding steps of resistance in the coil suspended in the transmitter. The resulting current flow is measured by the indicator, recorder and continuous count-up integrator. The accurate spacing of the contact rods provided the square root extraction of the differential so no cams are necessary for meters to read directly in units of flow.

Figure 9 illustrates a wide range oxygen meter of the same type. In some installations, the quantity of oxygen flowing for maximum operations is so many times that used for off-peak hours, that the low flow would be too far down the meter range to be accurately measured by the meter designed to catch the high peak flow. This wide range meter solves that problem. It is actually two complete meters, except that the red pen of one and the blue pen of the other record on the same chart. Pressure switches are provided which automatically switch the proper instruments to whichever electric transmitter is within its accurate range. Figures 10 and 11 show such an installation on the main oxygen line to 24 open hearth furnaces, where oxygen may quickly change from supplying a few to supplying many of the 24 furnaces.

This pneumatic transmitter is of the force balance design where the out-put air pressure must always be directly proportional to the measured force. It has features particularly suitable for oxygen flow measurement. As shown in Figure 12, the oxygen is confined to two completely metallic chambers by a stainless steel sylphon bellows, welded to the housing and to the balance beam. The complete absence of stuffing boxes insures against the serious hazard of getting grease in such a packing gland. Unusual speed and accuracy of differential measurement is obtained as the composition diaphragm is moved only a few thousandths for full range from low to high flow. This avoids the delay found in float type meters and those requiring time for mercury to flow between chambers. This time element is particularly critical when metering widely varying flows such as seen in charts of Figures 4 and 5. The simple pneumatic recorder or indicator shown in this Figure 12 is ideal if no total of the flow is desired, or if the flow is sufficiently constant to use an intermittent integrator.

The cross sectional view of this transmitter in Figure 13 shows the ease of changing its measuring range by changing the oxygen diaphragm area or moving the air diaphragm along the force balance beam to reset it for a new balance of forces. This makes possible a quick field change of meter range for the same transmitters and instruments without change of orifice. Additional installation and adjustment features of this pneumatic-electric meter are seen in Figure 14. This shows the simple mercury U-tube in the electric transmitter



PNEUMATIC-ELECTRIC FLOW METER

Figure 8 — A pneumatic-electric metering system.

where the accurately set rods instantly transmit any changes in the mercury level to the remote electric instruments.

Oxygen could be accurately measured by many more types of meters, if it were a constant flow, rather than the suddenly and widely changing flows usually encountered and illustrated by the charts of Figures 4 and 5. The watt-hour type integrator meets this difficulty by instantly following the changes in rate of flow impulse, and counting up a continuous total of the flow from second to second. In Figure 6 the features of the common house and industrial electric service meter are recognized. The electric integrator differs in only one respect. It will be noted that electro-magnets are used in this integrator in place of the fixed magnets of the standard watt-hour electric meter. This provides automatic compensation for any voltage variations. The counter is geared to the revolving watt-hour disc so that each slight or sudden change in rate is included in the integrator reading.

The remaining illustrations are photographs of a few typical oxygen meter installations and show some of these types of meters in operation. Each illustrates a good way of installing oxygen meters in existing mills, where space is usually at a premium, and transmitters are preferred near the pipe line, while the instruments are placed where they can be most easily seen and their information be used.

Two oxygen meters of the pneumatic-electric transmitter type are shown in Figure 15 in an Ohio steel mill. One measures the oxygen for hand scarfing and cutting of slabs, and the other for billet scarfing. The regulators are shown and the orifice in the oxygen line is connected to the pneumatic transmitter, from which the air is piped to the electric transmitter. This instrument panel for the slab scarfing line with its direct reading recorder and continuous watt-hour integrator is the left panel. A duplicate set of transmitters at the billet scarfing line are remote and are electrically connected to this panel at the right. The chart of Figure 9 is from a similar instrument panel in an Ohio steel mill instrument office which is about 1½ miles from the pneumatic and electric transmitters located at the point of measurement where the oxygen is supplied to the scrap yard.

At another Ohio steel mill, Figure 16 illustrates the installation of these pneumatic and electric transmitters inside the enclosed instrument panel of each of 11 open hearth furnaces for measuring oxygen for flame enrichment in each furnace. This provides short pipe connections to the oxygen orifice and easy access to the transmitters. Two meter bodies of a different design can be seen in this same view. They are of the buoyancy type for measuring the low differentials developed by the flow of low pressure coke oven gas, and the flow of air, across orifices. They are electric transmitters and remotely actuate the indicating, recording, and continuous integrating instruments on the panel.

The front of this enclosed panel is shown in Figure 17. The instruments include: oxygen indicator, recorder and integrator, carbon monoxide gas indicator, recorder and integrator, steam flow recorder and integrator, air flow recorder, furnace pressure recorder, oil flow meter and controllers for oxygen, combustion air, carbon monoxide gas, fuel oil and furnace pressure.

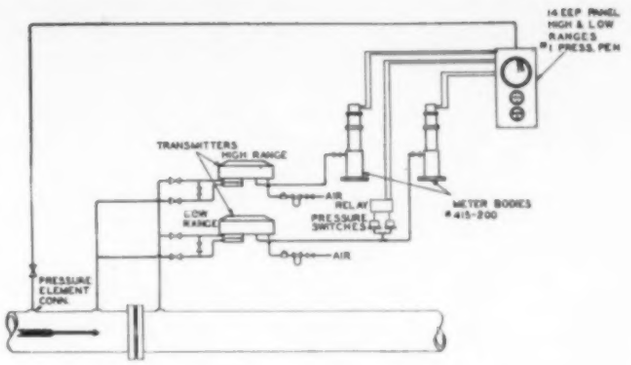
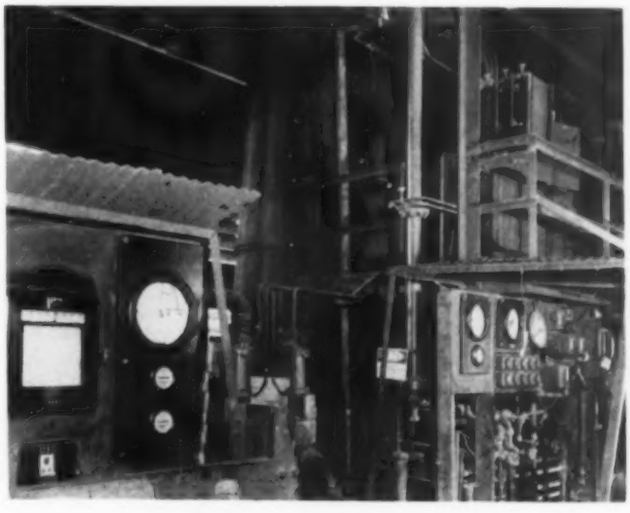


Figure 9 — The gas metering system shown has a wide range of 10 to 1.

Figure 10 — Two pneumatic-electric transmitter installations are used for this double range meter on an open hearth.

Figure 11 — Open hearth furnace panel unit for measuring oxygen is one of a number of such installations in this open hearth shop.



In a Chicago district mill where 24 open hearth furnaces are equipped with oxygen flow meters, Figure 10 shows most of the pneumatic and electric transmitter installation previously mentioned. This wide range meter measures all the oxygen to these furnaces and consists of high and low range transmitters of both the pneumatic measuring and electric transmitting types, with automatic switch to transfer to high or low flow rate. They are located in a sheet steel enclosure, adjoining the orifice in the oxygen line on the elevated pipe gallery. The electrically actuated 2-pen flow recorder and two continuous integrators are on the operating floor as shown at the left in Figure 11.

This photograph shows one of the open hearth instrument panels at this Chicago district mill as well as the instruments for the wide range meter on the main oxygen line to the mill. The recorder, separate large dial flow indicator and the continuous integrator at the left end of the large panel, measure the oxygen flow to a particular one of the 24 open hearth furnaces that are supplied with oxygen. In this case, the electric transmitter to these instruments is in the steel case

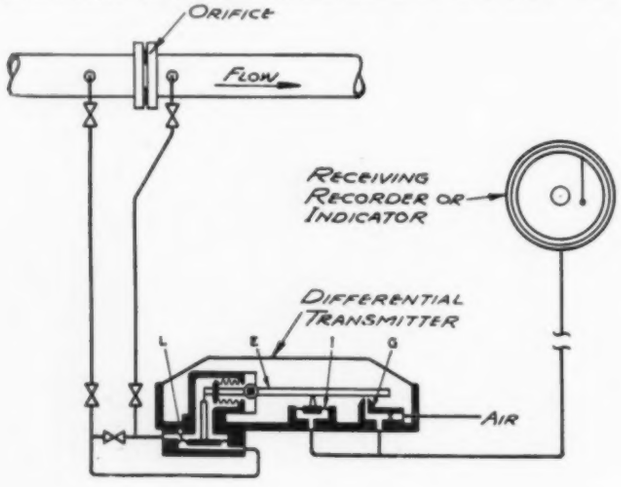


Figure 12 — Installation of differential transmitter for flow measurement.

mounted on the column directly above the panel, piped to the orifice plate in the vertical oxygen line shown. This is an electric ring balance type transmitter of the basic type shown in Figure 7, but designed for the higher oxygen pressure.

The oxygen meter of Figure 18 is of this high pressure electric ring balance design and was photographed at a Pennsylvania steel mill to illustrate a simple and effective out-of-door installation. This meter measures the oxygen supplied to a separate department using quantities for plate cutting and scarfing. The out-of-door line is directly above this meter housing. As the recorder and integrator are electrically actuated, they could have been remotely located at a central instrument room if desired. While this type of oxygen meter contains no liquids subject to freezing, it is easy to install a steam tracer line with steam coil in such a housing; or to use a good sized electric light, should it be desired to keep meters above freezing.

Probably the most complete master metering station which has been installed to meter oxygen being purchased is shown in part in Figures 2 and 3. This

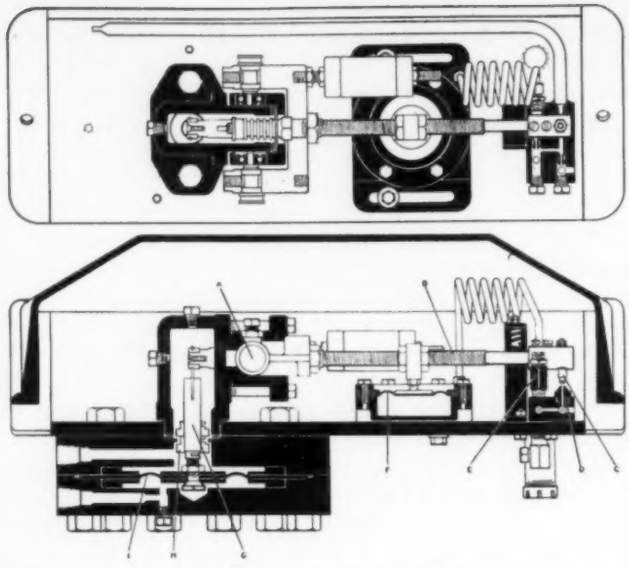
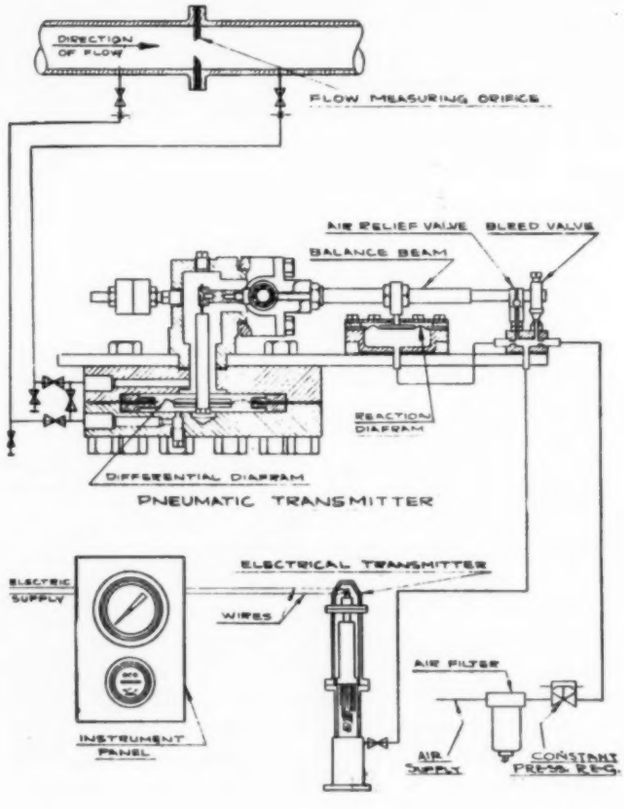


Figure 13 — Cross-section view of differential transmitter.

Pennsylvania steel mill made exhaustive studies of types and arrangements of meters to most accurately measure the substantial number of dollars of oxygen they purchase at their plant, by tank truck delivery. They selected the electric ring balance type electric flow recorder and the continuous watt-hour electric flow integrator. They studied the wide variations in their daily use of oxygen and designed and installed a combination of six of these meters in parallel. Automatic flow controllers in the first five of these parallel

Figure 14 — More details of the pneumatic-electric flow meter are shown in these sectional views.



lines actuate automatic shut-off valves in the last five lines.

Flow meter engineering in the full technical sense was produced by the fuel engineer of this steel mill, and the daily charts testify to his accuracy in forecasting the correct flow rates, orifice sizes and meter ranges for this battery of six parallel meters. Pressure compensation was also specified for each meter. Pressure compensators shown in Figure 3 automatically correct the readings of both the recorder and the continuous integrator for any variation in the pressure at its own orifice plate. Space prevents including a set of the charts from these six parallel meters to illustrate how precisely these were specified.

The automatic flow controller in No. 1 line opens the valve in No. 2 line before the flow in No. 1 line approaches the maximum capacity of No. 1 meter, and thus on to lines No. 2, 3, 4, and 5 as the oxygen flow increases, often very suddenly to maximum plant demand. Likewise, as the flow decreases in No. 5 line, its

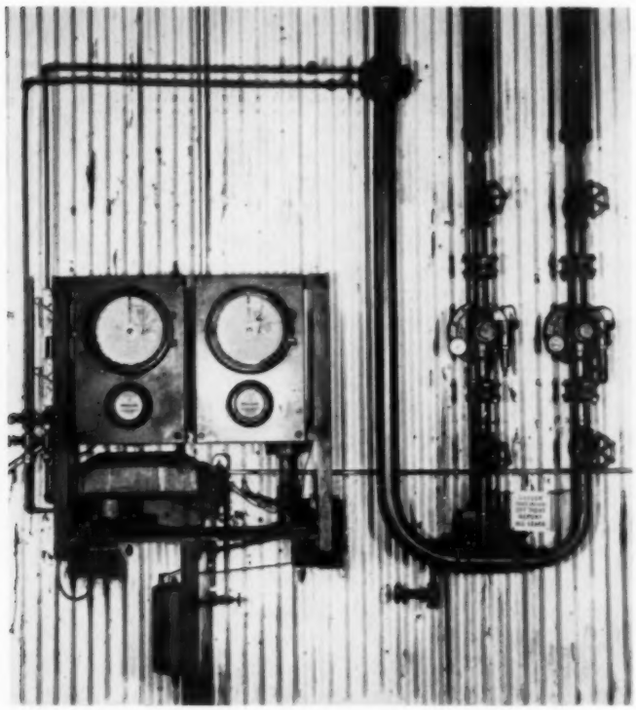


Figure 15 — The two oxygen meters shown are of the pneumatic-electric transmitter type.

controller closes the valve in No. 6 line to keep No. 5 flow within the most accurate range of that meter and so with lines No. 4, 3, 2, and 1.

The lines are 1 in. and 2 in. and the individual meter maximum capacities range from 600 cfhr to 36,000 cfhr, with the pressure compensators of the 120 psig class. Well over 500,000 cu ft are measured in many 24-hour periods by this most complete and accurate oxygen flow metering station.

In conclusion, it can be stated that oxygen is being used extensively in many leading steel mills and that its price makes it profitable to accurately meter its purchase, to distribute its cost by departmental metering, and to use it under the watchful supervision of a suitable meter.

Figure 16 — The pneumatic and electric transmitters shown in this photograph are installed inside the instrument panel of each of the open hearth furnaces which they govern.

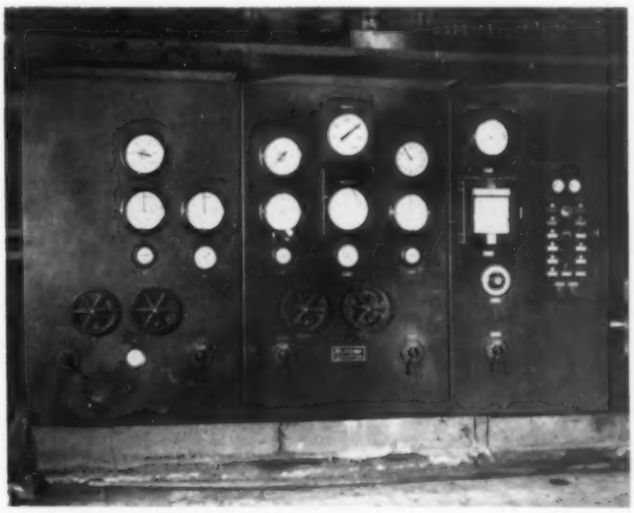
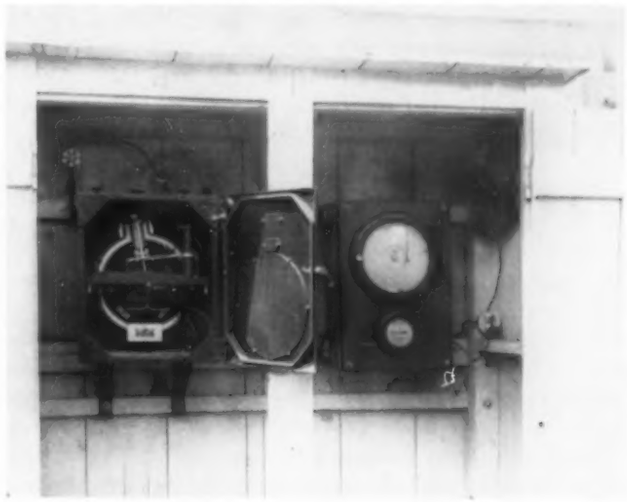


Figure 17 — Front side of the panel of Figure 16 is given in this photograph.

Figure 18 — The outdoor meter cabinet shown includes a high pressure electric ring balance design.



DISCUSSION

PRESENTED BY

EDWARD T. W. BAILEY, Chief Combustion Engineer, Steel Co. of Canada, Ltd., Hamilton, Ontario, Canada.

CHARLES W. PARSONS, Assistant to the Vice President, Republic Flow Meters Co., Chicago, Ill.

C. DAN HARTMAN, Mechanical Engineer, Bailey Meter Co., Pittsburgh, Pa.

E. J. W. EGGER, Service Engineer, The Linde Air Products Co., New York, N. Y.

MARTIN J. CONWAY, Consulting Fuel Engineer, Gap, Pa.

E. T. W. Bailey: Throughout Mr. Parsons' remarks, he stresses the advantage of continuous integration. For conditions which include intermittent flows for experiments of short duration, the continuous integrator may be more accurate. However, most applications of metering are for cost distribution purposes, and the integrated results cover a monthly period. In such cases, would not the intermittent integrator give practically accurate results? While it may fail to count on some of the peaks, it also is guilty of counting in the valleys. Has Mr. Parsons any data which would indicate the magnitude of integrator error over a monthly period for the intermittent as compared with the continuous integrator?

One of the most important aspects of oxygen metering is proper correction for pressure. If the average pressure at the orifice is not in accordance with that chosen for its design, which can easily be the case where bath lancing on one or more open hearth furnaces is practiced, results can be considerably out of line. The automatic pressure correction feature is justified for departmental distribution use. Practically all our oxygen meters have both automatic pressure and temperature correction, and to date our experience with these devices has been very satisfactory.

Charles W. Parsons: Mr. Bailey's question on the intermittent integrator is right to the point. While we have no suitable test data to offer, the charts of Figures 8 and 9 do show the difficulty of obtaining an accurate total with an intermittent integrator. Reasonably constant flows are easily totalled by such an integrator, which makes a determination of flow every 15 seconds. However, these typical charts of oxygen flows to lancing, cutting, and scarfing operations visualize the necessity for using a continuous integrator to follow those rapid variations in flow. Otherwise, many high and low flows will be completely missed in the totalled quantity, and a large error be accumulated.

Mr. Bailey's recommendation of a pressure compensator is noted. Variations in the lower pressures make such compensators well worth while. The type shown in Figure 18 compensate both the recorder and the continuous integrator.

C. Dan Hartman: Mr. Parsons' paper covers quite thoroughly the experiences we all have encountered in oxygen flow measurement. We in our company have come to the same general conclusions.

For open hearth, blast furnace, and general plant metering service, our standard bell and our area meters have proven quite satisfactory and give a wide range of accuracy themselves.

Low inertia, small displacement differential recorders of the bellows type have proven themselves quite successful for scarfing services. The bellows meter does not have a wide range of accuracy. Mr. Parsons has pointed out that at this stage of the game is where we do our selling. We simply sell you another meter and use a high-low meter range system. Our company feels that an escapement type integrator is satisfactory for intermittent flow service.

E. J. W. Egger: Mr. Parsons' paper gives many good reasons why users of oxygen distributed through piped systems should install meters. Measurement of oxygen consumption by meters has always been of particular interest to my company because it is an effective means of promoting economical use of piped oxygen. We have followed the improvements which meter manufacturers have developed for meters to be used in oxygen service with considerable interest, and there is no question that in the past five or ten years considerable progress has been made to take care of fluctuating flows.

It is interesting to note the manner in which flow rates that vary over a wide range have been taken care of by the use of multiple meter arrangements consisting of from two to as high as six meters installed in parallel. There is no question that such multiple meter installations provide for more accurate measurement, and the use of such multiple meter arrangements for wide flow range capacity brings out the fact that meters must be used in the range for which they are designed, otherwise the volumes they measure will not be accurately indicated or recorded.

There is one point which I do feel should be stressed, and that is that metering of oxygen is not the same as metering of air or other gases from the standpoint of safety. The importance of keeping oil, grease, or any other combustible material away from oxygen cannot be overemphasized. Only meters manufactured to observe these precautions should be used for oxygen service, and care should be observed in handling and installing oxygen meters to avoid contamination of internal surfaces which will be exposed to the oxygen with such objectionable materials.

Martin J. Conway: Mr. Parsons' paper refers to the measurement of one of the most costly gases used in the steel industry and is especially timely in its presentation. Purchased oxygen costs vary between $1.50 and $5.00 per 1,000 cu. ft. at standard conditions in bulk, depending upon the quantity used monthly, type of storage, method of transportation and other factors. Surely any raw material used in the manufacture of steel having these values should be scrupulously accounted for. This is particularly true where there is more than one consuming department. Furthermore, chart records of individual departmental consumption form reliable background data for analysis and study of operations over the long period sometimes necessary to establish sufficient operation information to draw dependable conclusions.

Mr. Parsons' reference to the master metering station of a Pennsylvania steel mill is also particularly interesting as this same method of step measurement has been successfully used in the distribution of natural gas to large industrial concerns for a number of years.

BETTER DOMESTIC AND INDUSTRIAL WATER SUPPLY

By CYRUS WM. RICE
Cyrus Wm. Rice & Co., Inc.
Pittsburgh, Pa.

. . . . ample supplies of cool water of high purity and low hardness flow through the Pittsburgh district and can be made available by the plan described in this paper . . . .

▲ A condition that has seriously prevented the healthy growth of many community centers in this country by not allowing for positive industrial diversifications, is the availability of domestic and industrial water supplies. The Pittsburgh area represents a case which is of particular interest to the steel industry. Here, the interest in a better domestic water supply was expressed recently in a rather positive manner, by an exceptionally large number of replies from dissatisfied users. These replies were in answer to questionnaires sent to consumers in each water district serviced by different water companies within the metropolitan area of Pittsburgh. When the replies were classified, it was found that the following percentages of dissatisfied users numbered:

100 from West View.
93.5 from the city of Pittsburgh.
95.0 from Wilkinsburg.
97.0 from South Pittsburgh.
87.5 from Bellevue.

A more intimate analysis of the questions asked each consumer showed that the following percentages of dissatisfied users were so for the following reasons:

78 bad taste and odors in the waters.
85 water too hard for laundry purposes and the high cost of soap and chemicals for the treatment of such waters.
78 water too hard for bathing purposes.
74 water was unsatisfactory for manufacturing purposes.
98 of the women were dissatisfied with quality.
78 of the doctors were dissatisfied with quality.

Many of the doctors reporting under "remarks" were dissatisfied because of the influence of these waters on health, principally because of stomach and intestinal disorders. A large percentage reported using purchased water for drinking purposes.

On the basis of the total replies, 98 per cent preferred water of mountain quality to those now being secured from our rivers. Of the total number of replies, only one-half of 1 per cent mentioned the correction of our stream pollutions as the remedy for supplying all-around satisfactory water for community and industrial purposes. The greatest number of complaints by the domestic consumer about the high costs of softening existing local water supplies for home uses is warranted, because it takes 13.6 pounds of the average laundry soap to remove 1 pound of such hardness and 10.5 pounds of the average bath soap for the same purpose. On the basis of recent chain store prices this cost of laundry soap averaged 29.8 cents per pound and 41.7 cents per pound for bath soaps. At industrial prices for soda ash this cost for removing 1 pound of hardness approximates 2 cents, which makes softening with laundry soap 202 times the cost of soda ash, and 220 times this cost when using bath soap. These results are all based on careful laboratory analyses of all kinds of common commercial soaps and therefore includes the minimum excess use of such soaps and soda ash for effecting the maximum removal of hardness from water.

For most industries, very exact means are employed in controlling the softening of water by which treatments are changed to meet the changing qualities of the water in use. Practically no control in the use of soaps exists with the domestic consumer, especially in laundry operations where the prevailing rate is usually large enough to soften the hardest water. This not only wastes soap, but much too often produces alkaline excesses that rot fabrics in the laundering processes. This in turn shortens the life of all such goods. These extra costs frequently exceed the actual cost of the water itself. If industries controlled their softening operations in the same "slip-shod" manner, the results at plants would be terrible, to say the least.

The substitution of soft water of near constant quality would make the regulated use of soaps and detergents in the home much more certain with the consequent minimum excess of these materials and minimum destruction of clothing caused through such abuses.

A survey conducted in 1944 among 500 of the larger industries in all kinds of manufacturing, much along the same lines as that for domestic consumers, gave the results in Table I.

Here is the over-all average, 61 per cent favored the use of water under 60F temperature; with 78 per cent the pH was important; 88 per cent favored constant quality water; 68 per cent favored water of mountain

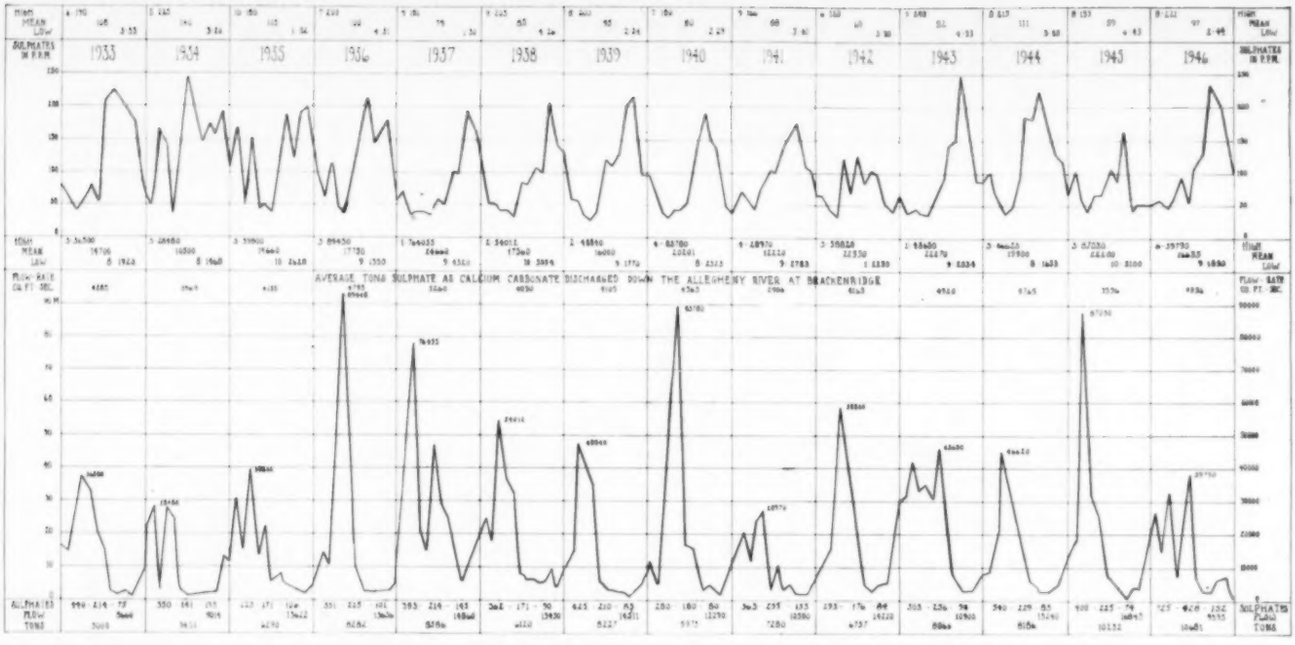


Figure 1 — The top curve is a record of the sulfates in the Allegheny River, and the lower curve gives the corresponding flow rates. Note that periods of low sulfate concentration correspond with high flow rates. The data given along the bottom of the chart gives sulfate concentration and flow rates for the corresponding periods in the Monongahela River. These data on the Monongahela River are, however, not plotted on the above chart.

TABLE I

Have waters under 60 F any value in your operations?

Answers	Steel, per cent	Textile, per cent	Paper, per cent	Miscellaneous, per cent	Over-all average, per cent
Yes	61	30	57	67	50 favored
Is pH of water important for your operations?					
Yes	61	80	80	80	78
Are constant quality waters of any value in your operations?					
Yes	78	90	90	87	88
Would "A" water of mountain quality meet all your requirements for processing without further chemical treatments?					
Yes	72	64	75	42	68 favored
Which water would you prefer to treat for steam power purposes?					
"A"	100	90	98	100	97

quality without further treatment; and 97 per cent favored the soft mountain water for steam generation purposes.

Figure 1 shows the principal cause for all these dissatisfactions. This is a graphic record of all sulfates contained in the Allegheny River for each month over 14 years, ending December 1946. Note that the quantity of sulfates in this record increases and decreases almost proportionately with the flow of water in this river. This is a radical change for monthly comparisons of daily samplings. It is much more radical when the analyses of daily samplings are compared with the daily stream flow rates in this river at the same time. Sudden changes of this kind make the proper chemical treatment of such water difficult for the largest majority of industries.

TABLE II

Year	Allegheny River		Monongahela River	
	Flow rates, cu ft per sec mean	SO_4, terms $CaCO_3$ tons/day	Flow rates mean	SO_4, terms $CaCO_3$ tons/day
1933	14,700	4,285	8,660	5,000
1934	10,500	3,969	9,014	3,430
1935	14,660	4,155	13,622	6,290
1936	17,750	4,793	13,636	8,282
1937	24,660	5,260	14,860	8,586
1938	17,560	4,030	13,450	6,120
1939	16,000	4,105	14,511	8,227
1940	20,201	4,363	12,290	5,973
1941	12,220	2,906	10,580	7,280
1942	22,330	4,163	14,220	6,757
1943	22,270	4,920	10,900	8,866
1944	15,900	4,765	13,240	8,186
1945	22,200	3,536	16,843	10,232
1946	16,635	4,356	9,393	10,631
....	17,700	4,260	12,520	7,420

Table II also gives a more detailed tabulation for both the Monongahela and Allegheny River waters. This shows the average tons of mine waste in each of the rivers for each month in the year, over each year since 1933. Here, in the last few years, the increase in this waste and corresponding high tonnage for the Monongahela River exceeded the early record nearly 100 per cent. On the other hand, this record for the Allegheny River over the same period shows a slight decrease in recent years.

Of the total acid waste as sulfates in the two

streams, less than 3 per cent comes from industries, 3 per cent from natural sources, and 94 per cent from mines. This approximates 3 ppm from industries, in an average total of about 89 ppm in the Allegheny River water and an average of 221 ppm in the Monongahela River over a period of 14 years, ending December 1946. By comparison, the amount of human waste discharged into the combined Allegheny and Monongahela Rivers by the city of Pittsburgh on the basis of the average combined flow rate for the same period is less than 1 ppm, dry basis.

The city of Pittsburgh uses approximately 150 cubic feet per second of water, mostly from the Allegheny River. On the basis of the high flow rate in the Allegheny River on March 16, 1936, of 347,500 cu ft per sec, enough water was wasted in a single day to take care of all of Pittsburgh's needs for 2300 days. This flow continued for nearly 48 hours. For the month of March, 1936, the water flow in the Allegheny River was at the rate of 89,448 cu ft per sec, for every second in the month. This was ample to supply the city of Pittsburgh for 18,500 days, or 30 cities of its size for nearly 2 years. Many high monthly and daily rates were not uncommon in this river over the years since 1933. Compared with low flows in the same river that averaged less than 1500 cu ft per sec for as much as 45 days in one year, this high monthly rate was 60 times greater. These high rates represent a terrific waste of high-grade water, all of which are periodic, occur in cycles, and are unpredictable.

TABLE III

Year	Allegheny River flow rate, cu ft per sec		pH at low flow rate
	High	Low	
1933	36,500	1,920	3.8
1934	28,480	1,468	3.8
1935	39,800	2,628	3.0
1936	89,450	1,350	4.3
1937	76,405	4,320	4.1
1938	54,012	3,554	5.8
1939	48,840	1,770	3.7
1940	83,780	2,523	5.7
1941	28,970	2,783	6.7
1942	58,820	2,230	6.4
1943	43,650	2,034	5.5
1944	46,620	1,653	4.7
1945	87,030	5,100	7.0
1946	39,790	1,850	3.7
1947	53,940	5,175	7.1
1948	49,530	1,640	4.3
1949	41,620	3,440	7.1

Table III shows the variation between the high and low flow rate and influences of the low flow rate on the pH in the river water. Here, the water in the Allegheny River carries the lowest pH and corresponding highest acidities in the years with the lowest flows. On the other hand, these same waters are alkaline, or nearly so, where the flow rates approximate 5000 cu ft per sec or over. Note 1945 and 1947. Correcting all the mine waste is a practical impossibility under existing conditions.

1. Because the sealing of strip or drift mine operations requires a continuous expense for maintaining these seals for abandoned mines or in constructing new seals, the appropriations for which legislators in the past have been very reluctant to grant. With mounting taxes, both state and federal, this inclination to appropriate public funds for this purpose will diminish.
2. Because mine wastes too frequently find natural openings or dissolve their way to streams, either as free acids or as neutralized products of lime, in which form they are about as unattractive to industries and homes from a cost standpoint as the original waste.
3. Because a lime treatment, which is about the only kind industries and mine operators can afford, is not the remedy for the production of desirable wastes for industrial and domestic uses for the same reasons.

The location of dams with the main object of keeping the flood crest in the rivers below the level that is dangerous to property and life, is also no real answer to the solution of this problem, because of the large waste of high-grade water during and after flood periods through such practices.

The only permanent solution for an all-time positive correction of both the acid and unsanitary conditions in our streams is to recover the maximum rainfalls from uncontaminated areas into permanent storage where they can be distributed as needed for maintaining the flow of water in the rivers that will guarantee to correct these conditions.

The actual production of high-grade water for industrial and domestic uses requires

1. Top surfaces or run-off areas that are practically free of agricultural lime and colloidal clay deposits.
2. Areas that are steep and lend themselves to deep storage with capacities for not less than 1500 days' retention period.
3. Areas practically free of mine, industrial, and community drainage.
4. Areas preferably at elevations above all sources of such drainage.
5. Areas where the underground water is highly alkaline.

Top surfaces practically free of agricultural lime deposits exist in Erie, Crawford, Warren, Forest, and Elk counties and the upper part of Venango county in the state of Pennsylvania, together with adjoining counties abutting the New York-Pennsylvania state line. This

Figure 2 — Extensive areas in Northern Pennsylvania are free of lime deposits as is shown by the map.

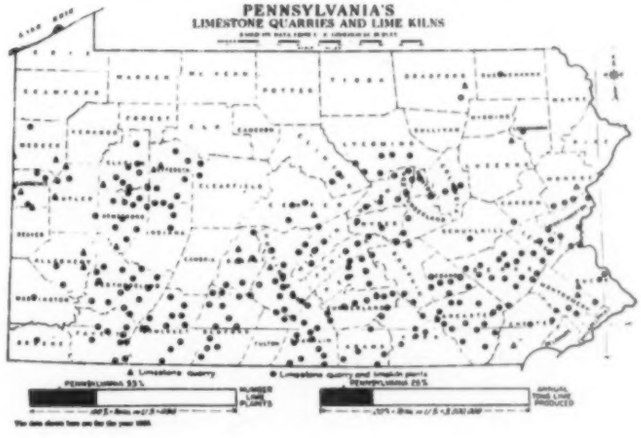


TABLE IV

Total Hardness in Waters from Supply Systems Located in Pennsylvania within Lime-free Run-off Areas

North of terminal moraine		South of terminal moraine	
East Stroudsburg	16.5	Cresson	15.0
Scranton	13.6	Torresdale	15.3
Wilkes Barre	18.0	Johnstown	23.0
Hazelton	13.8	Altoona	19.0
Carmel	9.3	Derry	23.2
Laurelton	9.7	Greensburg	20.0
Williamsport	10.3	Pottsville	12.4
Polk	9.5		
Average	12.6	Average	18.2

Total Hardness in Waters from Supply Systems Located within the New England States

Portland, Me.	12.0	New Bedford, Mass.	11.5
Lewiston, Me.	13.7	Fall River, Mass.	10.0
Howland, Me.	12.6	Lawrence, Mass.	19.0
Biddeford, Me.	12.0	Worcester, Mass.	11.8
Concord, N. H.	12.0	Northampton, Mass.	21.0
Keene, N. H.	12.0	Springfield, Mass.	18.0
Lacoma, N. H.	11.0	Thornton, Mass.	9.0
Manchester, N. H.	11.0	North Adams, Mass.	22.0
Gilman, Vt.	18.8	Montville, Conn.	19.5
Quechie, Vt.	58.1*	Norwich, Conn.	11.5
Montpelier, Vt.	84.0*	Bristol, Conn.	12.0
Rutland, Vt.	47.0*	Hartford, Conn.	17.0
Burlington, Vt.	56.0*	Waterbury, Conn.	21.0
St. Albans, Vt.	49.0*	Bridgeport, Conn.	12.0
Boston, Mass.	17.1	Norwalk, Conn.	27.0
Gloucester, Mass.	12.0	Providence, R. I.	27.6
		Pawtucket, R. I.	18.8
		Woonsocket, R. I.	00.0
		General average, New England	15.4

Note:—All hardness determinations are gravimetric in terms of ppm as $CaCO_3$.
*Not included in average.

is confirmed in Figure 2 from Smithsonian Institute records covering natural resources in the state of Pennsylvania. A second map from this same institute shows these same counties practically free of coal deposits. See Figure 3. The very best confirmation of this is through mineral analyses of silt deposits collected above the mouth of all small tributary streams in the Allegheny River basin, within the mentioned counties. A composite analysis of these samples gave the following percentages:

88.6 silica.
4.78 alum and iron oxide.

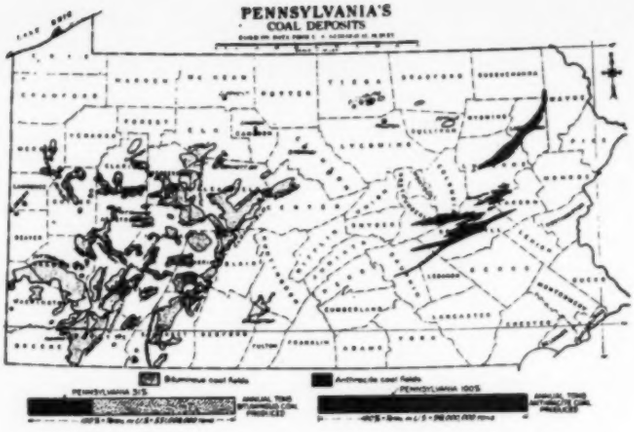


Figure 3 — Coal deposits in Pennsylvania are given on this map.

0.44 calcium oxide.
0.26 magnesium oxide.

The same lime-free areas exist throughout northern Pennsylvania to the Pennsylvania-New Jersey state line. The analysis of water from the total hardness such sources within this area confirms these qualities in the land. The same top soil also exists throughout the New England states, with the exception of Vermont. Analyses of water from these areas are shown in Table IV.

Here the hardness of waters in areas in northern Pennsylvania vary from 9.3 to 23.0 ppm, with an average of 15.4 ppm. The samples from streams north of the southern tip of the glaciated areas, or terminal moraine, averaged 12.6 ppm and south of this area 16.2 ppm. In the New England states spot samplings varied from 9.0 to 27.0 ppm, with an average of 15.4 ppm. Here the lowest average hardness was 12.0 ppm in the states of Maine and New Hampshire.

Troublesome clay deposits occur only in a very small area within the mentioned counties in Pennsylvania. The effects of these can largely be corrected through proper tree plantings.

Steep, quick run-off or top surface areas are important influences in both reducing the time contact of these waters with the mineral deposits in the top soil, and in reducing the time element for evaporation of water before it reaches the streams or any storage reservoirs located in the stream beds. This influence is

TABLE V

Run-off area	Ratio	Run-off	Square mile	Elevations	
				Gaging station	Reservoir
French Creek at Carters Corner	30.2 to 1.0	21.52	208	1235′	1340′
Clarion River at Piney	31.6 to 1.0	21.3	951	1230′	1520′
Tionesta River at Nebraska	27.5 to 1.0	21.4	469	1079′	1530′
Oil Creek at Rouseville	13.2 to 1.0	21.1	300	1028′	1320′
Sugar Creek to Sugar Creek	13.16 to 1.0	19.3	166	1016′	1320′
Brokenstraw to Youngsville	20.8 to 1.0	20.8	321	1187′	1350′
Weighted average per sq mile	25.7 to 1.0	21.3		1159′	1413′
West Branch Mahoning Newton Falls	13.1 to 1.0	11.36″	98	511	.....
Little Beaver, Liverpool	19.0 to 1.0	13.82″	505	703	.....
Little Shenango	18.0 to 1.0	13.65″	101	953	.....
	18.0 to 1.0	12.88		768	

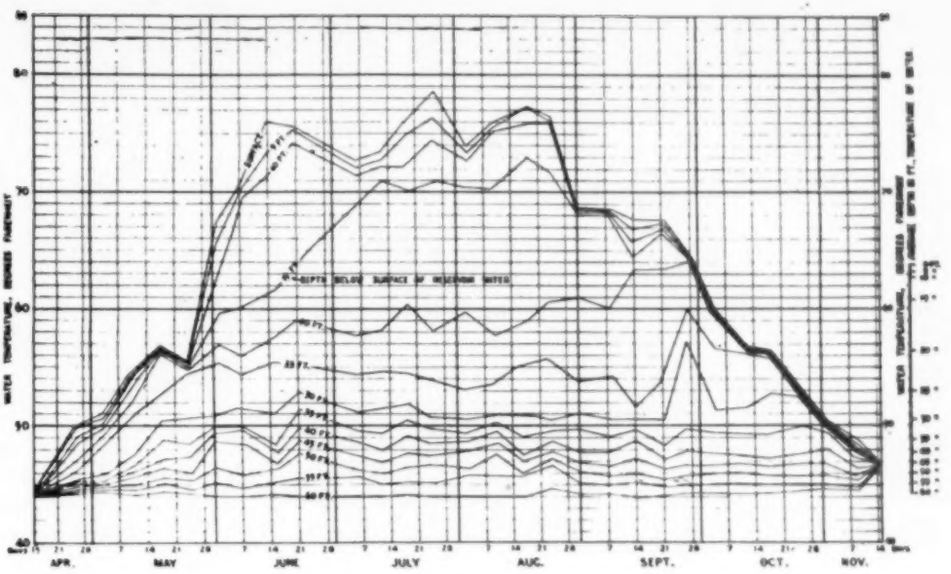


Figure 4 — The water temperature varies very little at depths over 40 ft below the surface, regardless of the variation in the air temperature, as is illustrated in this figure for Lake Cochituate which is located near Boston.

reflected in the comparison of stream flow records of the Department of the Interior for steep grades with those that originate in the lower flat run-off areas as recorded. Table V gives this comparison for a period of 10 years, ending December, 1941.

Here, with an average ratio in this comparison of 25.7 in the run-off to 1 ground water, the rain water delivered to the stream at an average elevation of 1159 ft was 21.3 in. At 768 ft elevation this delivery totaled 12.9 in. These records were from run-off areas in the same latitude. This shows a gain of nearly 70 per cent run-off to the streams per square mile in the higher elevations. While steep run-off areas are mostly responsible for this gain, the cooler temperatures in these higher altitudes influence this larger flow by decreasing the evaporations in the run-off areas in these altitudes.

Deep storage is necessary because the water for a depth of 30 to 35 ft below the surface absorbs the heat from the atmosphere during the warm summer months, and as such is not dependable as a source for cool water supplies for consumer users. This area is known as the thermocline, whose waters are in constant vertical circulation. The extent of this depends upon the amount of the heat absorbed from the atmosphere.

The area below the thermocline is mostly stagnant, and the temperature of the water stored in this during hot weather may vary from 41 to 55F. This again depends upon the depth and volume of water in storage, and volume withdrawals from this for consumer uses.

The cold waters in the bottom of deep storage reservoirs are nearly separate bodies of water, until the density of the waters in the top 30 to 35 ft through contact with winter temperatures, approximates the maximum density of water at 39.2F. See Figure 4. Circulation of water between the top and bottom then begins and continues over the cold months of the year. The bottom becomes stagnant again when higher air temperatures increase the temperature of the water within the thermocline. The value of this deep storage is most important for collecting and storing cold water during its greatest production over the cold months in the year. The capacity of this should be such as to meet the needs of the consumers for cool water during the longest period of hot weather on record.

The increasing demand for cold water by industries is growing by leaps and bounds. There is no need for presenting evidence of this because of the many published articles in newspapers and journals and the fact that many states have instituted measures for conserving on the use of ground water.

TABLE VI

	Temp water entering, F	Temp water leaving, F
1942		
July	59	62
August	61	62
September	64	62
October	64	61
November	61	58
December	56	54
1943		
January	52	50
February	50	50
March	52	52
April	52	54
May	54	56
June	58	58

Total hardness—24 to 136 ppm.

Table VI shows the temperatures for each month over the period of one year of water entering and leaving a 94-mile long conduit supplying the city of Oakland, Calif. The table shows there was no appreciable temperature loss in the water between the intake and discharge of this long conduit, and thus shows that the cool water temperature can be conserved over long runs.

Table VII shows the temperatures of water in 1942 leaving Salt Lick Reservoir which is used by a steel company in western Pennsylvania. The dam elevation of this at the top was 1435 ft. The average temperature here at the intake for September was 64.6F, with a water depth of 72 ft. The average temperature for July was 54.3 F, at an average depth of 88 ft, and for August was 57.7F at an average depth of 79 ft.

The influence of both depth and volume in controlling the temperatures of the water entering the intake is in evidence here.

TABLE VII

Salt Lick Reservoir, 1942 — Elev. Intake, 1435 Feet

Month	Water temp F			Height of dam in feet, ft-in.		
	High	Low	Avg	High	Low	Avg
January	38	37	37.5	92-11	91-8	91-7
February	38	37	37.7	92-1	91-10	91-9
March	38	38	38	92-6	91-10	91-8
April	42	38	42.1	92-6	91-8	92-1
May	46	44	44.5	92-1	91-4	91-8
June	50	46	48.2	92-2	90-4	91-3
July	56	50	54.3	90-2	83-7	88-5
August	62	56	57.7	83-5	76-7	79-2
September	66	60	64.6	76-6	71-2	73-7
October	60	50	54.3	79-8	68-3	72-0
November	50	42	46.9	89-0	79-11	84-3
December	42	36	40.4	92-10	90-0	90-8

TABLE VIII

Quemahoning Reservoir, 1941

Spillway elevation	1485 feet
Intake elevation	1435 feet
Surface water elevations, January, 1940	1456 feet

Average Temperature of Water at Intake, F

Month	High	Average	Low
January	36	36	36
February	39	35.5	35
March	41	35.0	33.5
April	42	40	38
May	46	42	41
June	51	46	42
July	54	48	46
August	59	51	51
September	58	57.5	56
October	58	56	52
November	52	46	40
December	40	39	37

Table VIII gives data for the same steel company from another reservoir in the same location and shows no temperature in excess of 60 F entering the intake.

The temperatures here also increased between June and September, after which the recession began and temperature was coldest during the cold months of December, January, February, and March.

The thermocline itself, because of its higher temperatures during the warmer seasons of the year, is the breeding area for germs, algae, plant life, etc. This does not exist in the cooler areas below the thermocline because of the cold water. The most desirable location, therefore, for the withdrawal of water is from the storage below the thermocline. Here the water in a well-planned system is invariably free of taste, odor, and suspended matter and is below 50F.

Any life, in order to exist in storage water, is dependent upon the amount and kind of dissolved solids it carries for the sustenance of such life. The speed with which water flows to any stream or storage, and volume of this, together with the composition of the soil in the run-off areas, have very important bearings on the growth of such life. The steep run-off areas and high percentage of rain water that is discharged to the streams in the higher elevations, together with the lime-free run-off areas over which these waters flow, is the best guarantee against this growth in the thermocline area.

The necessity for 1500 days' storage is also obvious for very definite reasons:

1. Because of the uncertain value of the water stored in the thermocline for supplying cool water.
2. Because of the uncertain amount of water lost through evaporation as influenced by weather conditions.
3. Because of the varying amount of rainfall frequently ranging from 10 per cent of normal to between 300 and 500 per cent in excess of normal.
4. Because it guarantees water of constant quality.
5. Because the long storage guarantees the maximum oxidization of iron and manganese.
6. Because it guarantees the maximum removal of all suspended matter to about the greatest degree of clarity without any filtration.

That a retention period of 1500 days' storage is not excessive is shown by the fact that Boston raised this retention period from nearly 400 days to a proposed 1400 days and now has 1700 days with existing abundant water supplies for all purposes. This was at a time when both New York City and northern New Jersey water consumers were threatened with a water famine with storage capacities that only allowed for less than one-fourth of the total retention period of the Boston system.

Again the collection of water into storage reservoirs at elevations in excess of 1300 ft in western Pennsylvania has the further advantage of delivering the water by gravity to all large community and industrial centers in western Pennsylvania and eastern Ohio. Water for industrial use may be drawn from near the bottom of the storage reservoirs where both the oxygen content and temperatures are lowest. This in turn will better the supplies for domestic use by increasing the circulations in the stagnant areas that prevail mostly in the bottom of such storage reservoirs during the summer months.

Where organic matters are removed from bottoms and sides of storage reservoirs before being filled, odors and taste in a supply water is no problem.

The quality of the underground water for tempering the alkalinity of the surface run-off water from these higher water producing areas is excellent.

This is shown in a weighted composite mineral analysis of water from 100 small tributary streams within the pure water areas in northern Pennsylvania counties, after an extended dry spell in August, 1944. The principal mineral constituents in this averaged a total hardness of 80 ppm, alkalinity of 60, sulfates of 17, and pH of 7.52.

A sanitary analysis under the same dry conditions from the same areas by an independent laboratory contained:

0.02 to 0.12 ppm manganese.
Under 0.001 ppm nitrate nitrogen.
0.06 ppm nitrate nitrogen and ammonia.

With the return of maximum rainfalls to storage, the hardness in the water for consumer use should with certainty not exceed 8 ppm when water from supply systems without this control in the areas above the

terminal moraine average 12.6 ppm. The water temperatures with deep long storage also should not exceed 60F.

Plans for collecting the better water from uncontaminated areas in the northwestern part of Pennsylvania were first started by C. C. Crick in 1929. The author's interest in this began in January, 1937, and was instituted at the request of a steel company client of long standing. The plans developed to date for this production are included in four construction phases. The basic facts, including the run-off and reservoir areas, together with the storage capacities, retention period, and number of streams in each construction phase, are shown in Table IX.

TABLE IX

Proposed Pennsylvania Aqueduct System

Phases	First	Second	Third	Fourth	Total
Storage—In billion cu ft	64.5	161.7	60.7	187.5	47.4
Daily capacity—In million cu ft	24.4	80.7	85.0	122.7	312.7
Days retention	2644	2005	715	1566	1500
Run-off area in sq mile	193	637	654	970	2453
Reservoir areas, in sq mile	57	112	62	90	321
Number of streams	25	19	26	30	110

Stagnant areas in the proposed system are reduced to the minimum through end and side branch interconnections for wide circulations between stream beds in the same elevation. Water is further aerated through interconnecting branches between basin systems at different elevations.

The names of principal streams, together with the elevations for each construction phase, are given in Table X.

TABLE X

Fourth Phase — 30 Streams

1500′—E. Sugar	A*	1500′—s.b. Tionesta	A
1500′—Kinzua	A	1500′—Salmon (Martinville)	T
1500′—4-Mile	T	1500′—Mill Stone	C
1500′—Arnot	T	1500′—Maple	C
1500′—Farnsworth	T	1520′—Spring	C
1500′—w.b. Tionesta	A	1520′—Big Bear	C
1400′—E. Hickory	A	1520′—Big Mill (Johnsonburg)	C
1500′—Little Bear	T	1745′—w.b. Clarion	A
1500′—Blue Jay	T	1745′—e.b. Clarion (Mt. Jewett)	A

Third Phase — 26 Streams

1400′—W. Hickory	A	1410′—Irwin	B
1400′—Tidiote	A	1520′—Federal	F
1500′—Andrews	B	1520′—Kelly	F
1410′—Brokenstraw	A	1400′—n.b. French	A
1410′—Blue Jay	B	1400′—e.b. Lebouf	F
1410′—Little Brokenstraw	B	1560′—French Creek, Erie City	
1410′—Matthews	B	1560′—20 Mile, No. 2	E
		1560′—Chautauqua	CL

Second Phase — 19 Streams

1318′—E. Pine	O	1318′—E. Lake	A
1318′—Thompson (Titusville)	O	1318′—Woodcock (Sagerstown)	F
1318′—Oil Creek	A	1318′—Little Sugar	F
1318′—Muddy	F	1318′—Mill	F
1318′—Big Sugar	F	1318′—North Sandy	F
		1318′—Little Sandy (Polk)	F

First Phase — 25 Streams

1104′—Little Pine	A	1310′—s.b. Slippery	BE
1104′—Dawson	A	1310′—n.b. Slippery Rock	BE
1130′—w.b. Bull Run	A	1310′—Wolf (Grove City)	BE
1130′—Thorne	CO	1345′—Big Scrubgrass	A
1310′—Bear	A	1310′—South Sandy	WS

*Capital letters opposite the name of each main stream into which it flows, as for example:

A—Allegheny River
B—Brokenstraw
O—Oil Creek
F—French Creek
T—Tionesta
CO—Conequenessing
C—Clarion
E—Lake Erie
CL—Chautauqua
BE—Beaver
WS—West Sandy

With the natural means that exist almost in Pittsburgh's backyard for the development of 2,500,000,000 gallons of cool, soft water at elevations over 1300 feet, an opportunity is available that has no duplication anywhere for eliminating the existing troubles caused by the increasing shortage of cool water in industrial centers in most sections of the country. The amount of this water can be increased nearly 1,000,000,000 gallons daily by adding more stream beds at lower elevations. By the constant replenishment of these through rains and cold weather the amount of cold water for industrial purposes is almost unlimited.

In the future, the community that can guarantee a supply of cool, soft water of constant quality, at low cost, will prove to be the greatest attraction for new industries and the expansion of present industries. The high cost of such water is the principal reason given in protesting its development. This is not true, because in similar developments unfiltered, soft, cool water is now being delivered wholesale at a cost of one cent per ton, which is slightly in excess of four cents per 1000 gallons. This is the wholesale rate of the Boston municipal water supply system.

The estimated cost of water for the proposed Pennsylvania plan at the reservoir, as based on a 4 per cent interest rate, is 3.87 cents per 1000 gallons before amortization, and $2\frac{2}{100}$ cents after amortization. Before amortization this cost, on a wholesale basis, when distributed through pipe lines within a reasonable distance from the reservoir, will approximate 5 cents and be less than 2 cents after amortization on the same basis. These figures depend on large volume sales to municipalities and industries, and vary above and below these figures according to the volume in use.

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DISCUSSION

PRESENTED BY

EMIL KERN, Vice President Charge of Engineering, Allegheny-Ludlum Steel Corp., Brackenridge, Pa.

CYRUS WM. RICE, Cyrus Wm. Rice & Co., Inc., Pittsburgh, Pa.

E. T. MORTSON, Fuel Engineer, National Tube Co., McKeesport, Pa.

E. J. REARDON, Vice President, Superior Steel Corp., Carnegie, Pa.

ELMER RESSLER, Assistant Resident Engineer, Jones & Laughlin Steel Corp., Aliquippa, Pa.

EARL A. NEEB, Plant Engineer, Allegheny-Ludlum Steel Corp., Brackenridge, Pa.

J. S. MURRAY, District Manager, Alliance Machine Co., Pittsburgh, Pa.

WALTER FLANAGAN, Fuel and Furnace Engineer, Carnegie-Illinois Steel Corp., Pittsburgh, Pa.

W. W. HODGE, Mellon Institute, Pittsburgh, Pa.

Emil Kern: I have listened with much interest to what Mr. Rice had to tell us. To a certain extent, I am familiar with his work, because I was one of those in this district who have hounded him from time to time with the question: "What can we do to improve the quality of the water we draw today from the rivers in this area?"

I am particularly interested in the following phase of his work. I would like to know just what this whole project really means, from a practical aspect, which people are working on it, who has picked up your thoughts, and particularly, I would like to know what is being done to bring this Pennsylvania Aqueduct plan, with which you have made us familiar, to some realization in the near future, or perhaps in the distant future?

I think we engineers really should make it our business to make ourselves somewhat more familiar with these problems, which today seem to be threshed out more or less by political people, for one reason or another. It is us, I believe, who are most interested in the quality of the water we get. Mr. Rice was talking before about the taste of the water, how hard the water is, how much soap we need to do laundering and things of that sort. Those are all things we are interested in. But, after all, our welfare, our personal welfare, is tied in with the welfare of the companies we are affiliated with, depending to a large extent on the quality of this water. Now, perhaps, Mr. Rice will tell us a little more about this aqueduct and just where it stands at the moment, if he is free to talk about that.

Cyrus Wm. Rice: You have had enough experience in your line of work to know you cannot sell a project of the kind under discussion to bankers unless you have enough orders to pay for the project. Objections are raised, more or less to the development of projects of such a magnitude that make it difficult to reach an agreement that will produce an order to purchase a proposed new water supply, if and when it is available. That was tried by Mayor Scully with his council, but this body would not go along with it. Mayor Scully, I believe, was sincere in wanting to get good water for Pittsburgh.

With projects of such magnitude you must first sell the water before you can get bankers interested. And, you must also obtain customers before you can get any water allotments from the state. That is a very definite requirement. Mr. Kern knows of the recent experience we had with Beaver Run Valley. It, also, takes more than one group of bankers to finance it, because of the great size of such projects. You can realize this difficulty best when you consider the fact that the first two phases would require better than 125,000,000 dollars to produce 800 million gallons.

New York City has been short of water because they do not have the storage capacity. This only amounts to 345 days and has proven serious.

The Allegheny River is sporadic, in its production of water, because where you have a lot of this suddenly and then you do not have any for a long period, it makes large storage necessary. This storage gives you a lot of water of constant quality. When it takes this 1500 days to pass through storage before it reaches the consumer, it must be uniform. With large deep storage, it is also much purer and cooler and very much better for industry.

What should be done among the steel industries here locally is to try to create a demand for better water. You definitely need cool water and cool water mostly is very scarce in the ground by comparison to this storage. When you do take it out of the ground, you also have water that causes depositions. With 1500 days' storage, and high percentage rain resources, you have water with no depositing properties. This water is, also, cool and in volumes 20 or 25 times the production per square mile run-off than can be obtained from most well waters. Such recoveries of rain water should prove of tremendous economic benefit to steel industries.

Areas of this kind are available in northern Pennsylvania for the production of such waters in any amount up to 2,300,000,000 gallons. The plan for this proposed project has been developed and expenses of this financed by myself and two associates.

A written promise from the council of the city of Pittsburgh to purchase waters, when and if they are made available at a price less than the existing costs of water to the city of Pittsburgh, would provide the means for starting such a project. Orders in the same amount from industries at about the same price, would permit of the same development.

Once this water is made available its high quality, low temperature and abundant sources by gravity feed would cause rapid expansion in its use with consequent lower prices to industries and the public.

E. T. Mortson: I have two questions: The four phases of water conservation Mr. Rice spoke about dealt only with the tributaries emptying into the Allegheny River. I am wondering what percentage of the water used in this district actually comes from the Allegheny River. What factors or studies are being made to take care of the water going into the Yough-

iogheny or the Monongahela Rivers? No doubt, a large portion of the men here represent companies using Monongahela River water.

Secondly, we would like to know whether we understood Mr. Rice correctly in saying that only 1 to 2 per cent of the total contamination in the river is due to city or industrial waste.

Cyrus Wm. Rice: Less than 1 per cent is human waste and under 3 per cent is industrial waste, and 94 per cent is mine waste.

E. T. Mortson: I am wondering why the city of Pittsburgh and the rest of the communities are spending so much money to pick up 3 per cent when we let the rest of industry put in 94 per cent?

Cyrus Wm. Rice: You have just stated the facts where they belong. Why the city and rest of the communities are planning to spend so much money is your guess as much as mine. The true answer to this correction of mine waste as I have already mentioned is to recover wasted rain water into permanent storage and feed it into the stream as needed to correct the mine acidity. This acidity kills the natural bugs in our streams, the kind that digest the solid organic pollutions under normal water conditions. Nature provides an abundance of this bug life.

The winter kill of plant life through freezing is far greater than anything from the municipalities, but a high percentage of this waste is destroyed in this manner by this same life before it reaches the streams. There is very little difference between the degree of these contaminations in the waters in the streams upstate and waters in the Allegheny River just above the city of Pittsburgh, because of this bug activity. These contaminations increase with the decrease in the flow of water in the stream, and become greatest in the river below Pittsburgh during low water flows in the river.

The rate of solid organic waste discharged into the river on the basis of the average volume flow of water down the rivers at Pittsburgh and total human waste from this area approximates 1 lb per 1,000,000 lb of water. This is based on facts developed by the U. S. Agricultural Department at Washington, D. C. Mine waste averages better than 90 times this in the Allegheny River and 220 times in the Monongahela. It reaches a peak of 725 ppm in the Monongahela and about 200 ppm in the Allegheny after protracted dry periods.

It is true that the correction of this 3 per cent through the expenditure of many millions of dollars for systems for the disposal of municipal waste will in no way modify or reduce any part of the 94 per cent of the mine waste discharged into the same streams.

It seems unwise, therefore, to spend large sums of money in this way when this better bug life and improved sanitary conditions it maintains can be assured through the recovery of flood waters into permanent storage to be bled later during dry periods in amounts that will definitely guarantee against acid waters.

We are fortunate in having such an average high rainfall and large watershed area in the Allegheny basin, together with a low capita per square mile above Pittsburgh to more than guarantee the volumes of waste rain water necessary for these purposes. This favorable condition does not exist in all river basins in the state.

Answering the earlier questions asked by Mr. Mortson, I believe better than 90 per cent of the water used by the City of Pittsburgh comes from the Allegheny River. Most of this is supplied by the city plants and only a fraction by the Wilkinsburg authority.

The only water supplied the city out of the Monongahela River is pumped and treated by the South Pittsburgh Water Co. There are no studies now that I know about for collecting waters from tributary streams of the Youghiogheny and Monongahela Rivers for purposes similar to that of the plan for the upper Allegheny River. The topography in most of the Monongahela River basin, which is less suited for these collections can, nevertheless, be used in a limited manner for pumping the acid conditions in this river.

This plan for recovering all wasted rain waters has many more advantages than this installation of municipal waste disposal plants, because:

1. It traps and holds flood waters from damaging property and lives in the tributary and main streams included in the plan.
2. It corrects the acid conditions in the tributary and main streams, thus permitting of unlimited fish life in these streams.
3. Supplies water for the production of firm electric power, which is another means for financing such a project.

Member: These pools that they have in the Allegheny River, are they just for retention of drinking water for the City of Pittsburgh?

Cyrus Wm. Rice: No, the pools are for navigation purposes.

Member: A man had an article in the Pittsburgh Press the other week, in which he was comparing the Pittsburgh supply with the New York City supply, and he said we would never be dry because of these pools.

Cyrus Wm. Rice: You have almost 20,000 square miles of water-producing area in the Monongahela and Allegheny Rivers. That is quite an area. Now, your low flow in the Allegheny River is as low as 1500 cu ft per sec, and 2500 cu ft per sec for the two rivers. Even so, when you multiply the seconds in a day you have nearly 1,500,000,000 gallons, which is 17 times the requirements of Pittsburgh under peak demands. But this is not good water; it is very high in solid content and is very undesirable for industries.

We work with industries all over the country and we know what they need. Pittsburgh will never attract the diversified industry, because the quality does not exist. You may find industries come here that manufacture something in the steel line, but when it comes to a textile or a rayon plant, a paper mill, or anything of that kind, we just cannot get their interest.

Member: I do not quite understand how the people on the Monongahela River, who get their water from that particular source, will benefit by your plan here. Would you elaborate on how we would get the water from the Allegheny River then?

Cyrus Wm. Rice: The water would have to be carried in some conduit, either direct to your plant or through the city mains, depending on the amount you want to use. If you are going into the wholesale end of

it, you want a big line; if you are just going to take water supply from the City of Pittsburgh as you may be doing now, then you will still get it from the City of Pittsburgh. But, you would have to run a special line if you want a large amount, because the city mains could not carry it.

Now, this water should be very cheap after amortization of the plan is completed. The cost figures I gave you, during the period of amortization, are based upon 4 per cent interest rate. An authority obtains money on about a 2 per cent interest rate. If this plan could be built by an authority, the rate of 3.7 cents per 1000 gallons would not exist, it would be more like 2½ cents. There is not another place in the country that equals this plan for upstate. It has all the facilities for quality production as there is nothing in the surface in the way of mine waste or lime deposit to cause any but very minor contaminations to your run-off, which constitutes your biggest source of water discharged into your streams and reservoirs.

E. J. Reardon: Mr. Rice, I know you have done a big job on water purification back in the east, and I remember you did a big job when I was at New Haven. I realize that this is a tremendous project you are thinking about here in Pennsylvania, which will involve a long period of time and a great expense. Unquestionably, at some later date, there will be such a project initiated, and, unquestionably put through, because the value of this water is so much greater than the other water that we can hope to obtain from any of the rivers which we have in this area.

I have worked on several of the bigger dams throughout the country, and I have also traveled through the northern part of the state. I realize that we are going to have a big job here in Pennsylvania to develop this water supply, such as you have covered, but probably your phases No. 1 and No. 2 would carry us for a long period of time and would put us in the position where we could get the type of water that you speak about, that we actually need down here in Pittsburgh.

Cyrus Wm. Rice: Do you know this water would have a head for its delivery to Cleveland at about 450 ft elevation?

E. J. Reardon: I own a farm up in this area at Meadville and that country up there you have your higher elevations. I also know the type of terrain and the areas and it is going to be a big project because of the number of streams and the number of dams required, and because of the aqueduct that you will have to use as connecting lines to carry it down through. But, as you say, the City of Cleveland is in about the same position as we are. They take in water about five miles out in Lake Erie, and it is not so good. As the years go by the value of good waters increases and, taken on the whole, our waters and utilities are about the cheapest things we have.

Cyrus Wm. Rice: In the City of Boston, the cost of water is 1 cent a ton, wholesale. When you say a cent a ton it sounds small, but when you take it per one thousand gallons, it is about 4 cents, which is about all it should be wholesale for large producers.

E. J. Reardon: I ran across the situation where the water came in tank trucks last summer, at $3.00 or $4.00 per one thousand gallons.

Elmer B. Ressler: I suppose, Mr. Rice, the aqueduct would closely follow the natural flow down the Allegheny River valley. Could you distribute the water then to districts on down the Ohio River?

Cyrus Wm. Rice: Yes.

Elmer B. Ressler: What area would you hope to cover down river in the project?

Cyrus Wm. Rice: There is an elevated strip of land, at almost the same elevation as the proposed aqueduct, almost all the way to Aliquippa. I went over that ground some time ago. Water from the aqueduct could, therefore, be carried through stream beds, almost to Aliquippa. You could carry it in the same way to the Ohio-Pennsylvania state line at almost the same level of 1300 ft. And, it would feed into one town after another, as far as Cleveland.

This would require an underground pressure conduit for distribution purposes.

Elmer B. Ressler: Do you not require some tremendously high dams?

Cyrus Wm. Rice: Yes, you do. But I believe the highest dam would be about 120 or 125 ft. They are all dirt dams.

Earl A. Neeb: What I wonder about is the authority to instigate this plan. Would that be a state authority or an authority set up by the City of Pittsburgh?

Cyrus Wm. Rice: I do not think you would get very far with private enterprise, under existing state regulations.

Earl A. Neeb: It needs publicity.

Cyrus Wm. Rice: It needs publicity, but mostly orders.

Earl A. Neeb: What would be the value to sportsmen, just from the publicity standpoint?

Cyrus Wm. Rice: I will tell you what the special commission for the City of Philadelphia recommended. They recommended that the banks of the reservoirs at the headwaters of the Delaware River be used for recreation purposes. They figured the water had to be filtered anyway, and recreational features, if under proper sanitary control, would not prove objectionable.

Earl A. Neeb: Could the same thing be done here?

Cyrus Wm. Rice: It could be done, but at Boston they do not allow it. At New York City, they do not. San Francisco is the same way, a lot of the cities do not allow the use of any abutting areas or waters for recreation purposes.

Earl A. Neeb: What I do not understand is, who is going to get back of it to get it started? It takes publicity and people's interest.

Cyrus Wm. Rice: Mayor Scully tried to get it started and if council had backed him up I think the job would have gone through, because that presents a demand of 90 or 100 million gallons a day. That would have been a starter for the first phase. This would cost some 40 or 45 million dollars and would include filters. That is not a lot of money to lay out for obtaining a highly satisfactory water for all consumer uses.

They were then talking about going up the river and getting water. Running a pipe line from there would be expensive; it would cost over $20,000,000 dollars alone. Then they would have had to pump it in because there is not more than 20 or 25 ft difference between the up-river source and Pittsburgh. This would require an additional expense.

J. S. Murray: Mr. Rice, are the states of Ohio and

West Virginia concerned or interested in this?

Cyrus Wm. Rice: No, nothing has been said about this to the state of Ohio. I do not know just how that would conflict with the law here. There has been some thought about running a pipe line to the borderline between Ohio and Pennsylvania and then turning it over there to some authority. But this means the diversion of water from the Allegheny River to some other source, which may conflict with our state laws.

In New York state, they overcome this when they made application for water in Pennsylvania. But this was for captured flood waters, which were being wasted and decision by the court gave New York City the privilege to use these recovered waters on this basis. Just how far this transfer of water from Pennsylvania to another state will be privileged must be determined by the courts.

J. S. Murray: They are concerned with the same problems in the eastern part of the state of Ohio.

Cyrus Wm. Rice: Sure they are, but they certainly do not have the quality or quantity of water we have. I showed you two records in my talk this evening, one from the low area and one from the higher elevations. At 1100 ft elevation, the water flow to the reservoir was 70 per cent greater than the low area. Ohio has no elevation comparable to that of Pennsylvania and rain waters, therefore, are largely evaporated before they could go to storage.

J. S. Murray: What I was wondering was whether they would participate in some of this cost, because they would benefit from it.

Cyrus Wm. Rice: I do not believe they would.

J. S. Murray: You know how bad the water is in the Ohio River at Wheeling and Steubenville; also the Mahoning River is bad at Youngstown.

Cyrus Wm. Rice: Not nearly as bad as the Monongahela. But the better water in the Allegheny River and larger volume of this makes the Ohio River supply better for Wheeling and Steubenville.

Walter Flanagan: I think in Pittsburgh we are in just about the same condition as we were when I worked at Youngstown, Ohio, only at that time Youngstown's water smelled and tasted much worse and was even hotter than South Pittsburgh water, and that is saying a lot. But the people were in just about the same state of education then as they are today in Pittsburgh. Also as Mr. Rice indicated in his reference to certain streams, the answer was not nearly as attractive as it is in Pennsylvania, because the water supply that could be dammed up and converted to domestic or industrial use was very much less, because the reservoir was very much shallower and the water warmer. However, the city of Youngstown, after many years of educational effort, together with the surrounding communities got together and had the State Legislature establish the Mahoning Sanitary Authority, an authority with the power to issue bonds that would not pyramid on city or county indebtedness, the bonds were to be retired and interest and other operating expenses to be paid from the wholesale sale of water. The people voted the necessary bonds. A dam was constructed on Meander Creek to impound a municipal water supply. Since that time Youngstown has had palatable water, and is fairly cool, although not as cool as the water Mr. Rice describes for western Pennsylvania.

It appears that the case in Pittsburgh and surrounding communities requires pushing until the natural inertia of the people is overcome or to state it more politely, until the majority is well informed.

Cyrus Wm. Rice: I think the predominating interest in this area is steel, and you steel fellows should get together and do something about it.

Walter Flanagan: I think the dominating influence is drinking water.

Cyrus Wm. Rice: The amount of this water is a small part of the daily requirements. Industries, and particularly your company, uses a tremendous amount of water. I would say the steel companies draw more water out of the Monongahela River than flows down that river during dry periods. The drinking water here is only a trickle. There has been talk about the Mahoning River. This river ran a temperature as high as 130F in summer. You never had that in the Monongahela River, nothing near it. This summer temperature is the answer to your unsatisfactory river supply. This is very objectionable for industrial uses during summer months.

Walter Flanagan: The acid content was very bad in the Mahoning at the time the water authority was established.

Cyrus Wm. Rice: Yes, but never as bad in acid content as the Monongahela.

Walter Flanagan: Not as bad, but objectionable.

Cyrus Wm. Rice: Oh yes, I would say as far as taste and high temperature are concerned the Mahoning is much more undesirable.

Member: What does it cost us to use the water now in the Monongahela?

Cyrus Wm. Rice: I gave you some figures on cost. Your average cost in the area, taking the Monongahela, the Allegheny and Ohio, varies radically, according to the source.

Member: No. I mean the cost to use it, the effect on boilers, and so on.

Cyrus Wm. Rice: The cost of the water in the Monongahela, treating and everything, I would say approximates about eight cents per thousand gallons for the average over the years. Sometimes it will not cost that much, sometimes it costs a whole lot more. The Allegheny River, on the average, costs six cents on the same basis. To soften 1000 gallons of the average domestic supplies from the Allegheny and Monongahela River, the cost is $5.16 with bath soap at 42 cents per lb, and is $3.65 with laundry soap at 30 cents per lb. By substituting water of mountain quality, the chemical cost of treating would be conservatively reduced 80 per cent for both domestic and industrial users.

If you have a constant quality of water in the home, not the qualities of river water that go up sky high and then have a sharp dip, the housewife would know how to control it. If you had a steady quality, as you would with water from large storage, your use of soap and detergents would be about the same at all times. This means even lower costs, because it voids the excess uses.

Member: Then it would soon pay for itself?

Cyrus Wm. Rice: Yes, your saving in soap would more than pay for your water bills.

W. W. Hodge: When I was Senior Fellow on the American Iron and Steel Institute's Fellowship at Mellon Institute, I was invited to three conferences in

Youngstown, Ohio. The fellowship was for studying the wastes disposal problems of the iron and steel industries and research to develop methods for treating the wastes so as to reduce stream pollution. At the conferences in Youngstown, different plans were considered for abatement of pollution of the Mahoning River, and for increasing the available water supplied for that city and its many industries. I recall the plan proposed, by the Corps of Engineers, U. S. Army, and other parties. for the construction of dams on certain upland streams, to impound water during the spring months and release the water during periods of low river flow in the summer time. It was pleasing to learn that progress has been made on these plans and a more regular water supply is now available. I have been very much interested tonight in the talk by Mr. Rice in regard to the large volume of good quality water which could be obtained for Pittsburgh and adjacent cities by construction of some dams on certain unpolluted waterways in northwestern Pennsylvania. Of course, the project would involve considerable expense, and the questions naturally arise as to whether such expenditures are necessary, and if the improvement in the water supplies distributed would warrant the investments involved.

A few years ago, the officials of New York City proposed augmenting the water supply of that city by diverting 700 million gallons of water per day from the upper waters of the Delaware River. As I recall it, the states of Pennsylvania, Delaware, and New Jersey opposed the proposition. A commission was appointed to study the situation. Data on rainfall over the shed, runoff and stream flow were obtained. A group of engineers and chemists made a stream survey including tests and analyses of the river water under varying conditions of stream flow. The conclusion of the commission was that if New York City should divert 700 million gallons of water per day from the upper waters of the Delaware River, the salt water from the ocean would at times come back to the intake of the Philadelphia water works. The matter was adjudicated with the decision to permit New York City to take up to 400 million gallons of water per day from the headwaters of the Delaware River. The construction of the necessary dams and aqueducts to bring this additional water supply to the nation's metropolis is not completed, which is one of the reasons for the present shortage of water in New York City. I was there last week and one sees signs in the buses, subway cars, hotel bathrooms, newspapers, in fact most every place you look, such as "Do not be a Water Waster," "Save Water," "Do not leave the water running, shut the faucets," etc. It reminded me of the old adage "We never miss the water until the well goes dry." The above statements indicate that the effects on the areas of land near the proposed dam sites and on down stream localities should be considered in any proposition for diverting waters from their natural courses. I presume these factors have been taken into consideration in the plans proposed by Mr. Rice.

With the large Allegheny and Monongahela Rivers flowing through the city, the amount of water is not what Pittsburghers are interested in, but it is the quality of the water. I was interested in the figures Mr. Rice gave on mine drainage, waste pickle liquor, and some other wastes. They checked closely with the data presented in the reports of the U. S. Public Health Service's "Ohio River Pollution Survey," started about three years before the beginning of World War II and completed shortly after the war commenced. I think that was the most extensive and comprehensive stream survey ever made in the world. One of the conclusions reached was that around 85 per cent of the sulfates in the Ohio River and its tributaries came from coal mine drainage, much of it from abandoned mines. The balance of the sulfates came from iron and steel plants, oil refineries and other industries which use sulfates in the production of useful products. So your figures do check. This project outlined by Mr. Rice does look big, but when you think of the distance Los Angeles and some other cities have to go for their respective municipal water supplies, it is not such a large project. However, it is a big proposition for a city of this size.

Cyrus Wm. Rice: The first question raised by Mr. Hodge as to whether the expense in building the proposed system is justified and improvement in the water supplies would warrant the investment is answered by numerous known facts:

1. The existing river sources, according to two surveys that were made would be unsatisfactory and undesirable to 85 per cent of the industries in the U.S., because of their changing qualities, high hardness, high temperatures, and high cost of conditioning. A survey among the domestic consumers in the metropolitan area of Pittsburgh confirmed these unsatisfactions to a greater degree.
2. The cost of conditioning the water of mountain quality for all consumer uses will approximate one-fifth the similar costs from river water.
3. The cost of the new water demand will not exceed 4 cents during the amortization period and not over one-fourth cent after amortization.
4. The tremendous volumes of water available by gravity flow would assure the greatest possible protection against fire.
5. The recovery of flood waters into permanent storage would prove to be the greatest protection against floods for all time, for all areas included in the plan.

Cyrus Wm. Rice: When you talk about costs, I do not think the final cost to the consumer enters into it when it is so low. This talk about your initial cost, of water is largely controlled by the interest rate on the borrowed money. If you can finance it through an authority it makes a tremendous difference in this cost. The first thought was a private corporation, but that, I believe, is barred by acts of the legislature.

W. W. Hodge: I think you would have to have an inter-county and municipal, or a regional authority for it.

Cyrus Wm. Rice: I believe you are right. In any event the cost to this city for water would finally be very low. After amortization this should approximate a quarter cent per thousand gallons. Even if you double this and it comes to half a cent, it is low. There are few places in the country you can get it for that. And another good thing about the plan is that the water will flow to you by gravity, and that it will always be cool and soft, and of constant quality.

National Tube Starts Operation of New Mills at Gary

. . . . another unit of National Tube Company's expansion program, going into service at the Gary Works embodies the latest features in tube mill design . . . .

▲ SPECIALTY steel tubing, both seamless and welded, ranging in sizes from ½ to 9 in. outside diameter can now be produced at the revamped and modernized Gary works of National Tube Co. Most unusual of the new equipment is the No. 3 seamless mill, a push-button installation that can shunt pierced shells from the piercing mill in any one of three separate directions, depending on the type of tubing to be rolled.

This mill, an entirely new development, features continuous rolling on a mandrel and incorporates the stretch-reducing process in twelve separately powered stands. Stretch-reduction is accomplished by speeding up each successive roll stand, the added speed from one stand to the next stretching the tube between them. The tension acts along the length of the tube and reduces its wall thickness. This method is especially suited to the manufacture of small diameter tubing in long lengths. Delivery speeds run from 850 to 1700 fpm.

A 160-ft cooling table of the rotating screw roller type oscillates the stretched and reduced tubes back and forth across the rollers approximately 6 ft. It is designed to insure delivery of straight tubes to the cold saw.

Three electric-weld tube mills built to National Tube Co. specifications are also part of the new installation, making possible the production of welded carbon steel tubes from ½ to 5 in. outside diameter.

For the manufacture of stainless steel tubular products, a special unit incorporates extensive equipment of the most modern design. All processing installations in the stainless steel unit have been selected for closeness of control and for the production of a high-quality product.

In addition to the new facilities, much of the original equipment has been modernized to meet the exacting demands of today's market. The No. 2 seamless mill, which was installed in 1930, has been rebuilt to manufacture alloy specialty goods up to 48 ft long in sizes ranging from 3½ in. to 9 in. outside diameter. Among the major improvements made on this mill was the installation of a 60-ft doughnut-type rotary furnace with 50 tons an hour capacity.

An automatic outlet-guide section trough for the No. 1 piercing mill is a new development providing automatic hydraulically controlled guiding of the mandrel bar and pierced shell. Water-cooled rollers installed on the ingoing side of the reheating furnace, ahead of the plug mill, is an unusual feature of this otherwise conventional roll-down furnace. Ahead of the continuous sizing mill is a 13-chamber in-line reheating furnace with complete automatic controls. These chambers are in a continuous line and grouped to provide six separate heating zones, each individually controlled by an electric eye.

A completely modern metallurgical laboratory has been provided in a centrally located building which has been remodeled and air-conditioned. In addition to standard equipment for determining the mechanical and physical properties of tubular products, a laboratory for analysis by the spectrographic method has also been installed.

To complete the modernization of the Gary Works it was necessary to rearrange and reorganize many of the auxiliary departments. General facilities and auxiliary equipment had to be expanded and a new sanitary sewer system built. Transmission lines were constructed for 60-cycle power to supplement the existing 25-cycle system.

NO. 3 SEAMLESS MILL AND FACILITIES

The No. 3 seamless mill is an automatic continuous seamless and Assel combination mill producing tubes

Figure 1 — A pierced round is shown leaving a conventional piercing mill of the No. 3 seamless tube mill.

in hot-rolled lengths of 45 ft in light-wall tubing and 25 ft in heavy-wall tubing. Sizes range from 1 to 3½ in. outside diameter.

There are two separate continuous lines of in-line heating chambers. The application of these chambers in a continuous line for heating rounds is new to industry. This is the first installation of its kind ever made. Each consists of 27 chambers, 19 chambers being used to bring the cold rounds up to the desired temperature and eight to hold or soak them to insure even heating.

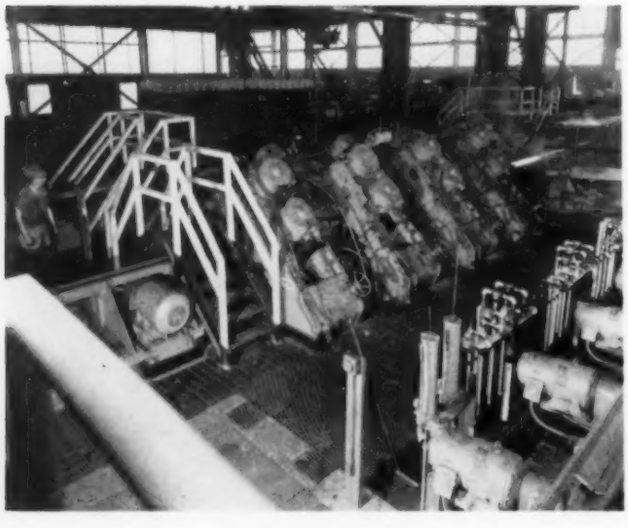
The 27 chambers in each line are grouped into six separately controlled zones, either gas or oil fired. Tube rounds are charged cold at predetermined lengths and are cut to the required piercing mill sizes by hot saws at the end of each furnace line. The tube billets then enter the piercing mill, which is of the conventional mannesmann type with the usual inlet and outlet troughs.

From this point the path of the pierced shell is determined by the type of tubing to be rolled. For small-diameter light-wall tubing, a mandrel bar is inserted and both mandrel and tube pass through the 8-stand continuous rolling mill. The bar is then removed and returned for the next tube while the rolled tube passes through the reheating furnace and on through the 12-stand reducing stretch mill.

The reheating furnace is a roll-down type with inlet and outlet water-cooled rollers. The furnace is 48-ft long inside with 3-zone control, equipped with furnace pressure, temperature and fuel controls.

Like the mandrel mill, the stretch-reducing mill is arranged with its successive stands located at right angles to each other, with each pair of rolls inclined 45 degrees to the floor level. The rolls of each stand have semi-circular grooves which alternately engage one side and then the other of the shell's circumference. By producing a speed differential between the successive roll stands, tension is produced in the portion of the tube between the stands. This tension stretches the tube and creates a thinner wall and greater length. In this way the stands are rolling the tube continuously thinner while also reducing its diameter.

Figure 2 — When small diameter, light wall tubing is being produced, the hot seamless tube's outside diameter and tube wall are reduced before further processing in this 8-stand continuous mandrel mill.



After leaving the stretch mill, the finished tube passes across a cooling table to a multiple cold saw where it is cut into lengths as required. It then moves to the scales for weighing.

When rolling heavy-wall tubing, after leaving the piercing mill the pierced shell by-passes the 8-stand mandrel mill and passes directly through the Assel mill. The mandrel bar is then removed and the tube passes on through the reheating furnace to the 12-stand sizing sinking mill. This mill is conventional with a common motor operating the gear-reduction drives and the line shaft. Again the tube passes to the cooling table and through the multiple saw to the scales for weighing.

When rolling large-diameter light-wall tubing, the shell is passed through the 8-stand continuous rolling mill but the Assel mill is by-passed. The tube is then reheated and passes through the 12-stand sizing sinking mill and through the rotary sizer. The latter is conventional, with the rolls set at an inclined axis. From this mill the sized tube moves to the cooling table, through the multiple cold saw and on to the scales.

The cooling table is 160-ft long and of a rotating screw-roller type. As the tubes are carried across, they oscillate back and forth across the rollers approximately 6 ft.

ELECTRIC WELDED TUBE FACILITIES

The new electric-weld tube mills were designed to produce tubes from ½ to 5 in. outside diameter. There are three, a 2-in., a 3-in. and a 5-in., each consisting of a forming section, a welding section with a rotary transformer to supply the welding heat, a sizing section for sizing and rounding the tube to specified tolerances, and a rotary-head traveling cut-off. The welding transformers are oil-cooled and are rated at 150 kva, 250 kva and 500 kva, respectively. Each one is supplied from its own generator with 180-cycle current.

Material for the electric-weld mills is provided from wide-band coils slitted to strip a proper size. Storage

Figure 3 — Stretch rolling elongates the hot seamless tube and reduces it to specified size. The illustration shows a heated seamless tube leaving the reheating furnace and entering the 12-stand stretch reducing mill of the No. 3 seamless mill.

space is provided for stocking approximately 3000 tons of 36-in. wide coils of about 14,000 lb each. This material may be either hot-finished, pickled and oiled or cold-rolled rimmed or killed steel, according to trade requirements. Additional space is provided for stocking single-width strip which has been rolled as required for the tube welders.

A complete slitting line was installed to handle all strip for the three welders. It is a combination drive and pull-through type slitter capable of preparing material up to 8 BWG (0.165 in.) by 36 in. wide. Handling facilities consist of a coil-loading ramp, an elevating-type charging buggy, a pay-off reel, recoiler, unloading buggy, banding stalls and scrap winder. Proper strip tension between the slitter and the recoiler is automatically maintained by electric controls.

To permit continuous operation of the 2 and 3-in. mills, looping and splicing equipment is provided. This equipment includes two splicers, each provided with a hydraulically operated up-cut shear with a clamping arrangement which automatically double shears the strip ends and clamps the squared ends into position for gas welding. The loopers, which were designed and built at Gary Works, accumulate 300 ft of metal which is paid out to the welders while the strip ends are clamped and welded. Coils charged to the 5-in. mill are rethreaded without end-welding.

Tubes from the electric-weld mills are transferred to the finish floor where rotary straighteners bring them to commercial tolerances. Following this operation they are cut to specified lengths on rotary-head cut-off machines. After passing through a battery of profilers, which end-face and chamfer the outside and inside diameter, the tubes are inspected and packed for shipping.

STAINLESS TUBE FACILITIES

Because of the exacting performance required of the finished product, an extensive installation for handling and processing stainless tubular products was installed at the Gary Works. The stainless production unit occupies a main building 160 ft wide and 744 ft long equipped with facilities of the most modern design. For proper conditioning of the seamless hot-rolled tube prior to cold working, a unit of three abrasive wet-grinding machines is employed to remove surface defects. For further refining the surface, a battery of polishing machines using abrasive cloth belts of various grits is employed.

Figure 4 — Seamless tubes delivered by this rotating screw roller-type cooling table in the No. 3 seamless mill are remarkably straight.

Numerous portable devices are available for the conditioning of small sections of the internal or external surfaces of the hot-rolled hollow billets. Boring equipment is provided for a thorough conditioning of the entire internal surface.

In a 60 x 80 ft room is located a separate pickling unit provided for "in process" material. The pickler consists of five vats—two steel water rinse tanks, two acid tanks and a salt bath for descaling. The descaling unit is a molten salt bath held at 950 F which, in combination with a water quench, will remove all evidence of scale without attacking the metal. After the salt bath, the tube is dipped in two acid solutions, followed by a hot-water rinse. Each lift of tubing is handled by an overhead crane controlled from a glass-enclosed room centrally located outside the pickling room.

Located beyond the main pickling room, a group of four tanks is available for cleaning and lubricating purposes. Here each load of tubing is cleansed prior to annealing to insure a clean product.

Three types of annealing equipment are used to process the wide range of sizes and grades of tubing manufactured. A gas-fired, three-unit, doughnut-type continuous furnace anneals tubing within the range of 3 to 8⅝ in. outside diameter. This furnace has a rated capacity of 1500 to 3000 lb/hr, depending on size and wall thickness of the tube. Product below 3 in. outside diameter is annealed in a continuous furnace heated by gas-fired radiant tubes. This furnace, 30 in. wide and 15 ft long, is equipped with water-cooled silicon carbide rolls. It has a rated capacity of 1000 lb/hr. For small light tubing from ¼ to 3 in. outside diameter, an electric induction annealing furnace is employed. It has a rated capacity of 500 lb/hr.

Each of these furnaces can develop temperatures up to 2150F. Sighted on the tube are radiation pyrometers which record and control the tube temperature as it passes from the heating chamber to the water quench at the outlet. Each furnace is equipped with variable-speed conveyors to insure proper treatment of any size processed.

Stainless tubing 3 in. outside diameter and under is reduced in another department which is equipped with two 3½-in. tube reducers, three 2½-in. tube reducers and five 1½-in. tube reducers. Cold-drawing equipment in the stainless department consists of two 50,000-lb and one 150,000-lb drawbenches. One of the former is equipped with a reeling device to permit the drawing of stainless products over a bar. To cover the range of point sizes required in the cold-drawing operation there is one ¾-in. and one 2-in. rotary swager and one 800-lb hammer.

A complete complement of finishing equipment is available. This includes a 12-roll straightening machine

with a capacity up to 2 in. outside diameter, a gag press straightener for 2 to 4½-in. tubing, one two-roll straightener with a capacity up to ¾ in. outside diameter, and one five-roll straightener with a capacity up to 4½ in. outside diameter. There are also two units of two cut-off machines each, complete with conveyors. One has a capacity of 2 in. outside diameter and the other of 6 in. outside diameter. Each unit is equipped with adequate stops to permit accurate cutting to the most exacting dimensions.

Testing equipment consists of a coupon press with plugs, pins and gages to perform the manipulations required for each specification. One hydrostatic tester for tubing up to 4½ in. outside diameter is provided for pressure testing. This equipment can exert pressures up to 3,000 psi. Tubing above 4½ in. outside diameter is sent to an adjoining unit where the straightening, cutting and hydrostatic testing is performed.

Final pickling, or "passivating," is performed in a unit of two pickling tanks and a water rinse. This unit is equipped with an individual crane operated from a floor position at the extreme end of the pickling tanks. The crane has two hooks, each individually controlled. This arrangement permits lifts of tubing to be elevated at various angles, facilitating complete drainage. After a final rinse, the tubing is blown out with live steam and air. There are four internal belt-polishers and additional external polishing equipment to produce surfaces in the grit requirements of the customer.

In addition to frequent spot checks throughout the manufacturing process, the finished product must undergo final inspection. For this purpose two inspection and packing tables are located near the pickling room.

Figure 5 — Steel strip is shown being formed and welded on the electric weld tube mill at the Gary, Indiana Works of National Tube Co. Material for this mill is provided from wide band coils slitted to strip of the proper size.

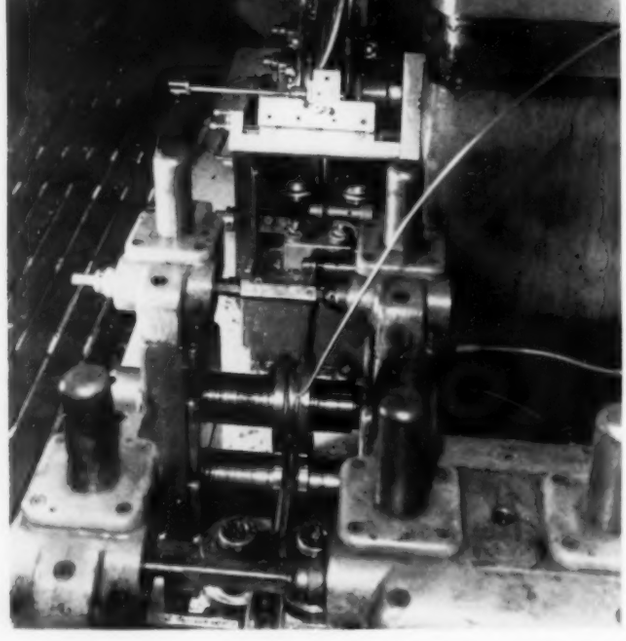


Figure 6 — Overall view of the doughnut-type rotary hearth billet heating furnace in the No. 2 seamless mill. This furnace heats billets preparatory to piercing. The discharging machine is in the foreground, while the charging machine is at the left.

NO. 2 SEAMLESS MILL

The most important of the original equipment to be renovated under the modernization program at National Tube Co.'s Gary Works was the No. 2 seamless mill. Originally built in 1930 to manufacture pipe and casing in lengths up to 48 ft, the mill was shortened to 35 ft during World War II to permit installation of additional machinery and reheating furnaces for alloy specialty goods. Under the post-war program, the mill was again changed to manufacture alloy specialty goods up to 48 ft long in sizes ranging from 3½ to 9 in. outside diameter. This alteration necessitated the removal of reheating furnaces and relocation and redesign of other pieces of equipment.

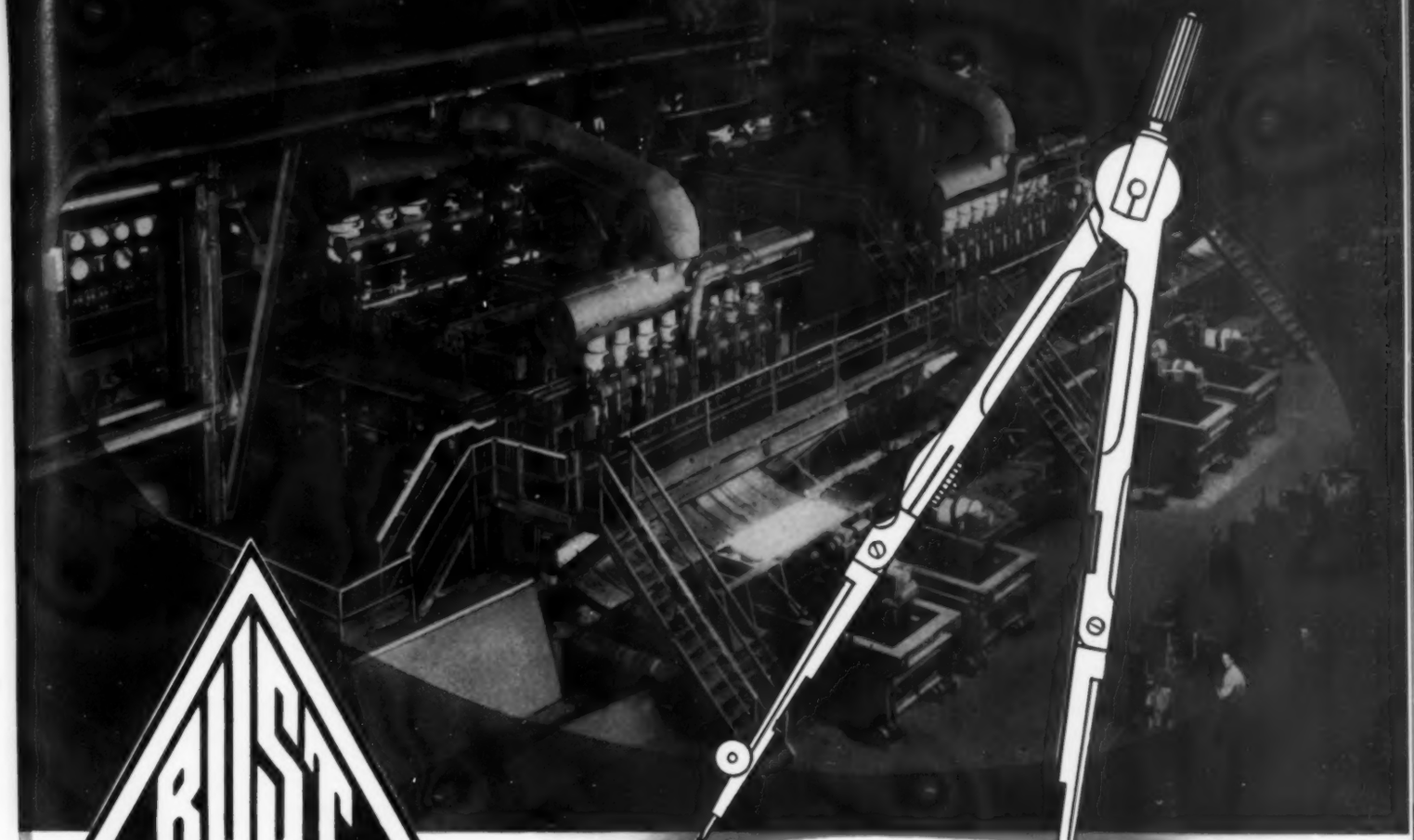
Among the major items of new equipment are a 60-ft doughnut-type rotary furnace of 50 tons-an-hour capacity, an automatic outlet-guide section trough for the No. 1 piercing mill, a reheating furnace ahead of the plug mill and a 13-chamber in-line reheating furnace ahead of the continuous sizing mill.

The rotary furnace is designed to incorporate five individual walled zones, each with its own separate furnace controls, and equipped to burn oil or gas, or oil and gas in combination. A machine automatically feeds cold rounds as required onto a conveyor. The conveyor, in turn, is automatically activated from the discharge end of the furnace by the manually operated discharging machine.

FINISHING FLOORS

Two finishing floors handle the full range of seamless products manufactured on the No. 2 and No. 3 mills. No. 1 floor is located near No. 3 seamless mill and processes both hot-rolled and cold-drawing tubing from 3/16 to 3½ in. outside diameter. No. 2 floor is located near No. 2 seamless mill and can handle tubing of 3½ to 9 in. outside diameter. Both floors are equipped with straightening machines of various types, cut-off ma-

A TRIUMPH IN ENGINEERING...



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...with ZONE-FIRED CONTROL

DESIGN MAKES THE DIFFERENCE

Leaders in the steel industry have reason to prefer Rust's patented zone controlled, double or triple-fired, recuperative, continuous furnaces for reheating slabs, blooms, billets, bars or other shapes. No other furnace gives such positive control of heating quality and tonnage output. Each is individually designed to meet specific needs and provides 100% accuracy in the control of predetermined soaking chamber heat for any required rolling temperature. Flexibility is achieved by simply changing rate of fuel fired in the heating zone. The result is uniform heating efficiency with a minimum of fuel.

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PROCESSING DEPARTMENT

Tubing other than hot-rolled requiring further treatment, such as pickling, doping, cold-tube reducing, cold-drawing, pointing, normalizing, intermediate and final annealing, is processed in this department. The furnaces are of the continuous roller-hearth type for normalizing and bright annealing and of the convection type for imparting structure and tensile properties.

The cold-working division consists of drawbenches of 20,000 to 300,000-lb capacities and tube reducers handling tubing of 1½ to 3½ in. outside diameter. The 20,000-lb, high-speed multiple drawbench is new. Other changes consist principally of streamlining the handling of material by relocating the necessary equipment.

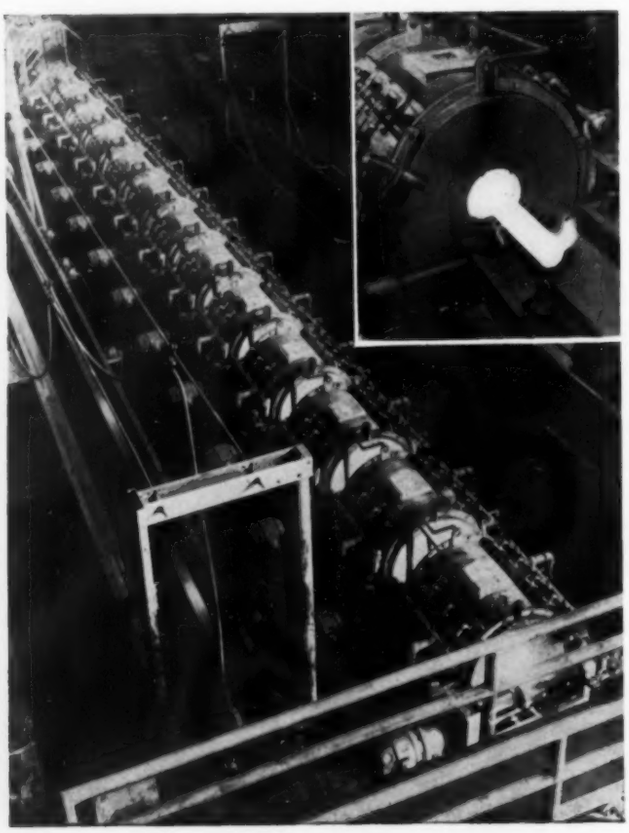
METALLURGICAL LABORATORY

To keep pace with the new and renovated equipment, a centrally located metallurgical laboratory was begun in 1948 and completed in the spring of 1949. The building is completely air-conditioned for both summer and winter to provide the clean atmosphere required for precision equipment and for comfort of the employees.

In addition to tensile, hardness, torsion, impact, magnetic and metallographic facilities for determining the mechanical and structural properties of tubular products, a complete laboratory for analysis by spectrograph has been installed. This equipment makes possible a more complete analysis in less time than by conventional methods.

Figure 8 — Faster, more accurate analysis of products is made possible through the use of spectrographic equipment in the new air-conditioned metallurgical laboratory.

Figure 7 — This battery of 13 furnaces reheats the seamless tube before it enters the continuous sizing mill. The inset shows close-up of a reheated tube leaving the line.

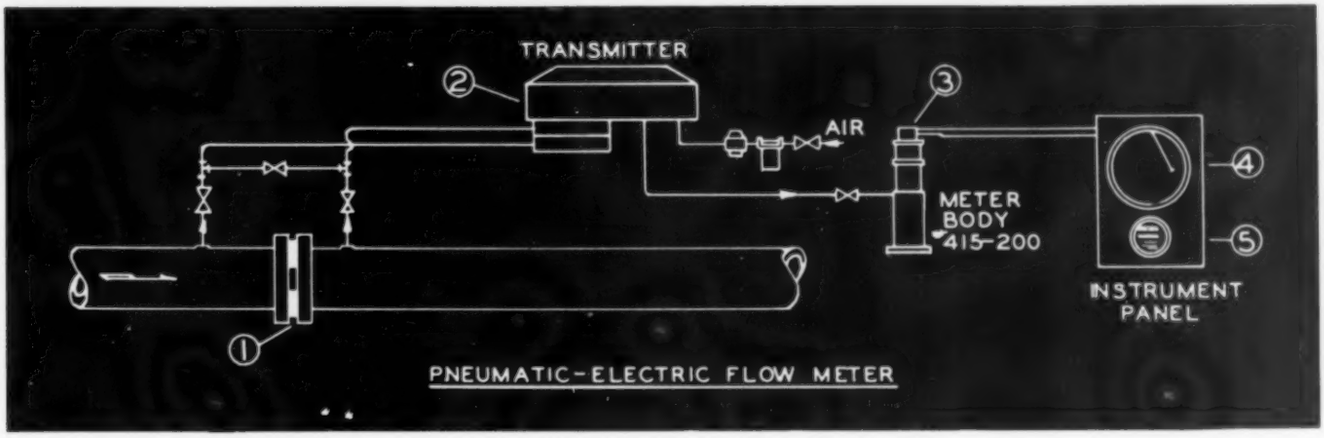


GENERAL UTILITIES

Power used throughout the original Gary tube mill was 25-cycle. All new equipment purchased was 60-cycle, so new power lines were needed throughout the plant wherever new equipment was installed. This necessitated the construction of 2600 lineal ft of concrete ducts, requiring 910 cu yd of concrete, and the installation of 10 miles of 4-in. fiber duct and 10 miles of lead-covered cable. A total of 270 miles of wire was used and 65 miles of conduit laid. To supplement the plant's compressed air capacity, two 2700-cu ft, 100-lb air compressors were added.

Roadways within the plant were rebuilt or resurfaced as required, and the parking area for employees was relocated and enlarged to provide for 600 automobiles. This parking area brings the employee closer to a new pedestrian tunnel built for his convenience. A bus loop was also constructed to permit entry into the plant for loading or discharging of passengers at the entrance to the pedestrian tunnel.

A complete new sanitary system discharging into the city's sewage disposal plant was installed to collect the plant's sanitary wastes. An addition was made to the main office, while the old section was completely renovated. Air-conditioning was provided throughout the new and remodeled sections. A new fire station and a new plant production control center were built. Other miscellaneous auxiliary buildings, including the steam boiler plant, were modernized. To complete the post-war program at National Tube Co.'s Gary Works, the various plant transportation systems were enlarged and new narrow and standard-gage rolling stock and automotive equipment were purchased.



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Here is an oxygen flow metering system that will accurately integrate the rapidly fluctuating flows encountered in steel mill operations.

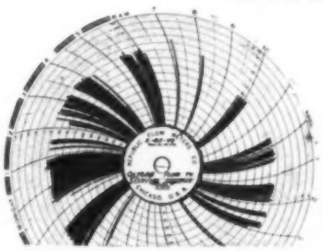
SENSITIVE METERING SYSTEM

The flow metering system, shown diagrammatically above, is a combination pneumatic-electric system for measuring a rapidly fluctuating flow of oxygen. It consists of:

1. ACCURATE ORIFICE METERING
- No moving parts in the flow line.
- No stuffing boxes with grease to develop hazardous conditions.

2. PNEUMATIC TRANSMITTER
- Differential measurement of highest sensitivity.
- Oxygen confined by housing of suitable metals.
- No stuffing boxes.
- Stainless steel or Monel sylphon sealing bellows.

3. AIR ACTUATED ELECTRIC TRANSMITTER
- Converts air loading to electric current flow proportioned to oxygen flow.
- Suitable for electric transmission to distant instruments.
- No moving parts.



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- Equally graduated charts, direct-reading in flow.
- Permanent record of rates of flow.
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- Accurately follows all sudden changes of flow.
- Not the intermittent type taking spot readings.
- Completely independent of recorder.
- No clock involved.
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For those installations where wide ranges of flow are encountered, a Republic pneumatic-electric metering system can be installed with a range of approximately 10 to 1. By a special piping arrangement, the range of accurate flow measurement can be extended to approximately 50 to 1.

The Republic pneumatic-electric flow metering system is completely described in Bulletin No. 48-2.

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"We stopped both useless shutdowns and motor burnouts from Single Phasing by installing Fusetron fuses in a refrigeration compressor circuit"

Glenn F. Buschman, Manager
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Mr. Buschman continues—

"In December '47 we rewound a motor for the Rund Packing Company of Lafayette, Indiana that had been burned out on single phase.

"One week later the same motor came back, again burned out on single phase.

"We investigated and found that the motor was used on the refrigeration compressor and that starting currents were causing the 100 amp. 250 volt renewable fuses protecting the circuit to blow. When one of them blew it single phased the motor.

"The thermals in the starter were oversize and so the motor burned up.

"100 amp. FUSETRON dual-element fuses were installed in place of the ordinary fuses and the thermals changed to the proper size.

"The thermals have so far never had to operate because the FUSETRON dual-element fuses stopped the useless blows on the starting current. This automatically stopped the single phasing that had previously caused the motor burnouts."

FUSETRON FUSES GIVE 10-POINT PROTECTION

TRUSTWORTHY NAMES IN ELECTRICAL PROTECTION

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1★ **Protect against short-circuits.**

2 **Protect against needless blows caused by harmless overloads.**

3 **Protect against needless blows caused by excessive heating — lesser resistance results in much cooler operation.**

4 **Provide thermal protection — for panels and switches against damage from heating due to poor contact.**

5 **Protect motors against burnout from overloading.**

6 **Protect motors against burnout due to single phasing.**

7 **Give DOUBLE burnout protection to large motors — without extra cost.**

8 **Make protection of small motors simple and inexpensive.**

9 **Protect against waste of space and money — permit use of proper size switches and panels.**

10 **Protect coils, transformers and solenoids against burnout.**

★ Fusetron fuses have high interrupting capacity. Tests conducted by the Electrical Testing Laboratories of New York City in December 1947 showed that on a 240 volt 60 cycle 3 phase, 4 wire circuit set to deliver 50,000 amperes, 30, 60, 100, 200, 400 and 600 ampere 250 volt Fusetron fuses on each and every test cleared the circuit without belching flame and with comparatively little noise.

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Fusetron DUAL-ELEMENT Fuses

Give All-Purpose Protection

because . . .

The fuse link element opens on short-circuit — the thermal cutout element protects on overloads — the result, a fuse with tremendous time-lag and much less electrical resistance.

They have the same degree of Underwriters' Laboratories approval for both motor-running and circuit protection as the most expensive devices made.

Made to the same dimensions as ordinary fuses — fit all standard fuse holders.

Obtainable in all sizes from 1/10 to 600 ampere, both 250 and 600 volt types. Also in plug types for 125 volt circuits.

Their cost is surprisingly low.

Don't Risk Losses

One needless shutdown
One lost motor
One destroyed switch or panel

may cost you far more than replacing every ordinary fuse with a FUSETRON dual-element fuse

MAIL THE COUPON NOW
for complete information about Fusetron Fuses and their 10-point all-purpose protection

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Please send me complete facts about FUSETRON Dual-Element FUSES.

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750

BETHLEHEM EMBARKS ON MAJOR MODERNIZATION PROGRAM AT JOHNSTOWN PLANT

. . . . the following excerpts are from a speech by Arthur B. Homer, president, Bethlehem Steel Co., given before the Johnstown Chamber of Commerce, June 6, 1950, describing the improvement program at the Johnstown plant . . . .

▲ "Now, I shall cover in a more specific way the new modernization and expansion program which Bethlehem is proceeding with for the Johnstown plant.

"Our plant here has certain handicaps, both in production costs and in competitive location, which can be counterbalanced only by the most intensive efforts. For instance, we are obliged to pay a premium on the transportation costs of iron ore, as compared with our biggest competitors. Also, sitting here on top of a low volatile coal mine has no longer the cost advantage that it once had, for modern methods require high volatile coking coal in the fuel mixture and we have to bring in 65 per cent of our coal from the outside.

"The topography of the country presents great difficulties in obtaining efficient arrangements of our facilities. The plant is actually a combination of a series of smaller plants built at different times and strung along the valleys. Due to this condition, it has been necessary to move all kinds of materials such as ingots and pig iron back and forth between Franklin and Lower Works in order to follow the proper sequence of steel-making operations. Compare our present arrangement, involving inefficient cross hauling, with the streamlined flow of materials in a modern plant and you will appreciate some of the handicaps we labor under here.

"Add to these difficulties decreasing market potentialities caused by the rise in transportation costs, and by the location in the Pittsburgh area of major competing companies which in certain ways are better located as to costs and markets, and you have a very good picture of the problem which confronts us.

"To put it concisely, it is this: Unless major and costly changes are made, this plant is bound to become a marginal producer, working only when business is at its peak. It is marginal now in certain respects and will become more so without certain essential improvements.

"Now Bethlehem has a good reputation. The Johnstown plant has a good reputation. But we cannot live on reputation alone. The products of the Johnstown plant are excellent and there is a market for them. Therefore, we are going to make the necessary changes. We are going to spend the money — the huge sum of over $32,000,000, and we are going to have a real competitive plant.

"Briefly, this is what we intend to do. We are going to consolidate at Franklin the operations of all our regular blast furnaces, open hearths, blooming mills and billet mills. In other words, Franklin will make all the basic iron and open hearth steel and will roll all blooms, billets and slabs. We are also going to make at Franklin all the coke needed for these operations.

"At the Lower Works the bessemer converters and the 48-in. blooming mill will be taken out of operation and the 18-in. billet mill there will be moved to Franklin. The two blast furnaces at the Lower Works will make ferro-manganese only, and will draw their entire coke supply from Rosedale. This program will eliminate all the wasteful cross-hauling and provide a more efficient flow of materials.

"Now this is not going to mean any decrease in steel ingot capacity. On the contrary, we expect to step up the steel ingot capacity from the present annual rate of 1,900,000 tons to 2,160,000 tons, an increase of nearly 15 per cent.

"This will be achieved by rebuilding all the Franklin open hearths and increasing their individual capacity from 135 to 150 ton heats. We actually started that job about the first of the year and six furnaces have been completed. The remaining fifteen are coming along at the rate of about one a month, and this part of the program should be finished in less than a year and a half from now.

"With this change we shall also install bigger cranes to handle the larger heats; we will have more efficient charging machines of a new type; new open hearth control equipment; more scrap buggies; more ingot cars and other auxiliary equipment. In other words when we finish, the open hearth steel making facilities will be the equal of the best.

"To balance this rate of open hearth capacity we are increasing the pig iron capacity of the Franklin blast furnaces by 216,000 tons annually. We will do that by enlarging three of our five blast furnaces at Franklin and by installing more efficient blowers, additional stove capacity and gas cleaning equipment.

"Our next problem is to get sufficient coke at Franklin to support the blast furnace division. Recently we built a new battery of coke ovens at Franklin, and we are now in the process of rebuilding another. This should be ready to go into operation about the first of next year, when we shall take the third unit out of pro-

Continental

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Designed and built by Continental with full complement of auxiliary mill equipment.

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STEEL CASTINGS

20 TO 250,000 POUNDS

duction for rebuilding, which should take about another year. When this is completed, we shall be able to produce over 112,000 tons of coke per month at Franklin, compared with a present output of approximately 76,000 tons.

"Now let us take a look at what we are going to do with the mills. We have now at Franklin a 40-inch blooming mill and a 34-inch billet mill, both in good condition. To these we are going to add a new modern high-lift 54-inch blooming mill. The 18-inch billet mill, in its new location at Franklin, will be modernized. These units will be capable of handling all the rolling, including the slabbing for the Franklin plate mill, and it is planned to scrap the 34-inch slabbing mill at Franklin. The 134-inch plate mill at Franklin will be relocated there to provide space for an efficient arrangement of the new blooming mill and the 18-inch billet mill.

"The new arrangement will give a modern streamlined lay-out with up-to-date mills, with efficient handling of material, and with blooming mills, billet mills and billet preparation all under one roof. We expect to have all the new mills in operation in 15 to 18 months.

"Each of the old blooming mills is now served by its own small, old-style soaking pits for heating ingots. Under the new set-up all the smaller pits will be torn out and replaced by a single group of thirty large modern units. This will not only materially decrease our fuel bill, but it will also result in far better heating which is so important to quality at this stage of steelmaking. Work on these pits is already under way, and the entire installation is expected to be ready for use in about fourteen months.

"As you may well understand, a great deal of electric power will be needed for all these new facilities which are motor driven. Some of our electric generating equipment was installed a long time ago and is no longer efficient, so we shall add a modern 20,000 kilowatt turbo-generator to supply the additional requirements.

"I have now described the principal changes we plan to make here at Johnstown. When these changes are completed there will remain very few of the original Cambria facilities taken over by Bethlehem in 1923. As I have said, we have already rebuilt most of the finishing units, and we are proud of their ability to make intricate sections of all types. With our revamped steelmaking facilities of modern type feeding our present finishing facilities, we shall have a real plant here at Johnstown that we can be proud of.

"In an industry like ours a plant must continually adapt itself to every important technological and engineering advance in order to keep ahead. Without the modernization program which we are now putting through, the Johnstown plant would soon lose out in the struggle for markets. Employment and payrolls would most certainly feel the effect."

WANTED!

There is a constant demand for copies of "The Modern Strip Mill", published by the Association of Iron and Steel Engineers.

If your copy is not in use please get in touch with us.

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When your Grab Bucket Cranes are "Shaw-Box," operational efficiency and dependability are assured. You can anticipate outstanding records of efficient, low-cost load handling and trouble-free operating dependability. "Shaw-Box" Grab Bucket Cranes are recognized for these qualities in mills all over the country.

Engineered to withstand the most severe and exacting demands, they are so designed that excessive wear and failure will not occur, even under the most unfavorable conditions. Simple, rugged, and extremely accessible, they have extra values built into them which insure dependable performance at all times, on the toughest kind of work. That is the "Shaw-Box" way.

"Shaw-Box" Grab Bucket Cranes fully conform to AISE specifications. They are built to give you real service with a minimum amount of attention and to be available without you paying a price premium. For the work they do, "Shaw-Box" are the least expensive Grab Bucket Cranes you can buy.

For the greatest value in dependable, superior crane service your purchase dollar can buy, look to "Shaw-Box."

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SHAW-BOX CRANE & HOIST DIVISION
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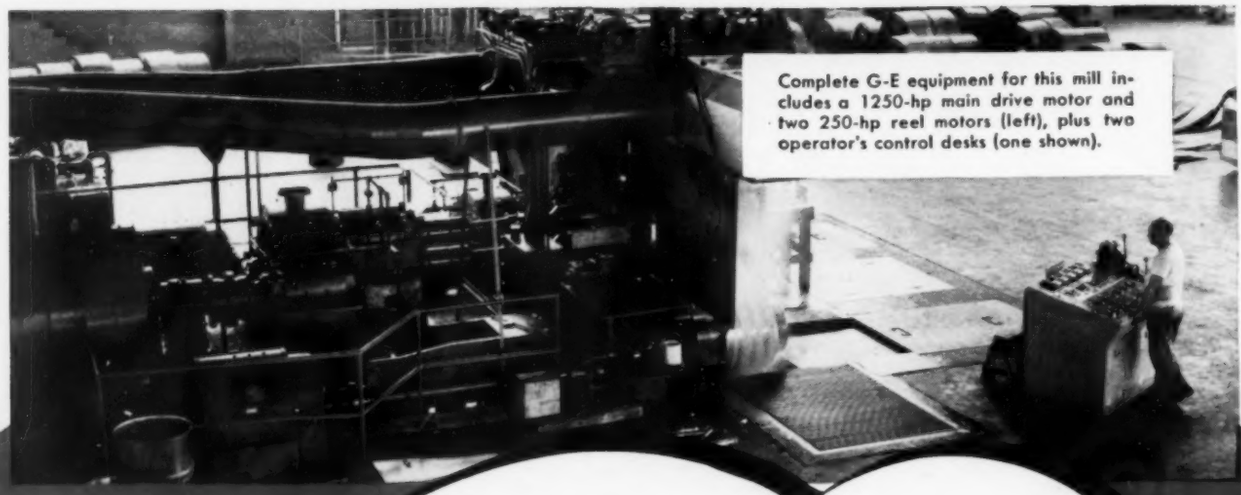
Builders of "Shaw-Box" Cranes, 'Budgit' and 'Load-Lifter' Hoists and other lifting specialties. Makers of 'Ashcroft' Gauges, 'Hancock' Valves, 'Consolidated' Safety and Relief Valves, 'American' Industrial and 'Microsen' Electrical Instruments.



Complete G-E equipment for this mill includes a 1250-hp main drive motor and two 250-hp reel motors (left), plus two operator's control desks (one shown).

G-E drive for 24" reversing cold-strip mill

maintains strip uniformity, simplifies threading and jogging, boosts "on gage" tonnage!

Here's another in a long list of General Electric steel-mill drives engineered for close quality control, ease of operation, and high output. Installed on a 24" 4-high reversing cold-strip mill in Detroit Steel Corporation's Eastern Mill Division, New Haven, Conn., this drive:

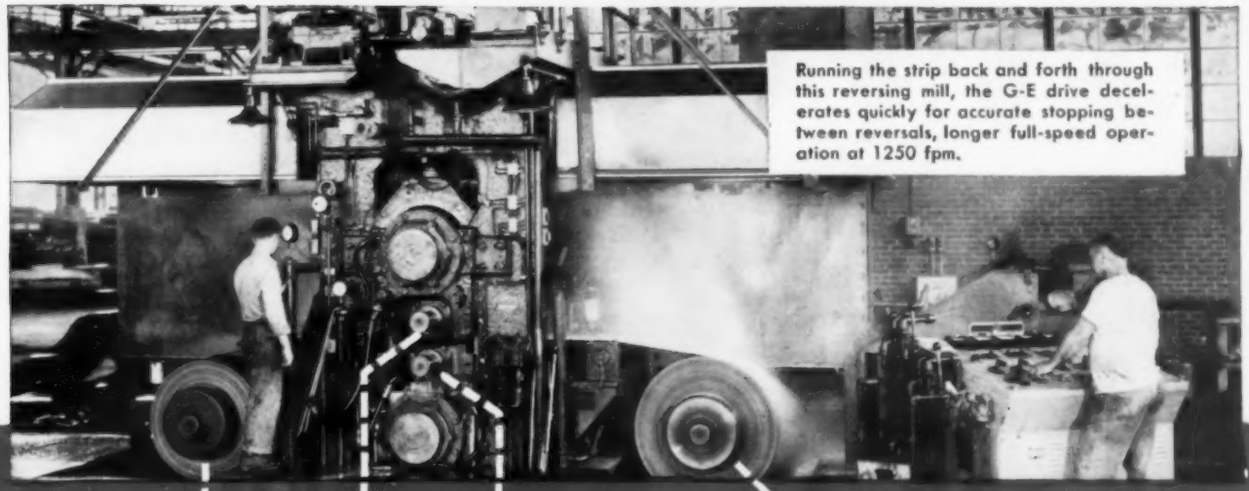
Holds uniform tension at all speeds, which provides uniform gage and surface, reduces strip breakage and roll marking.

Operates either unit independently, in either direction, without disturbing the other. This simplifies threading, permits holding stalled tension on one reel while jogging the other into position.

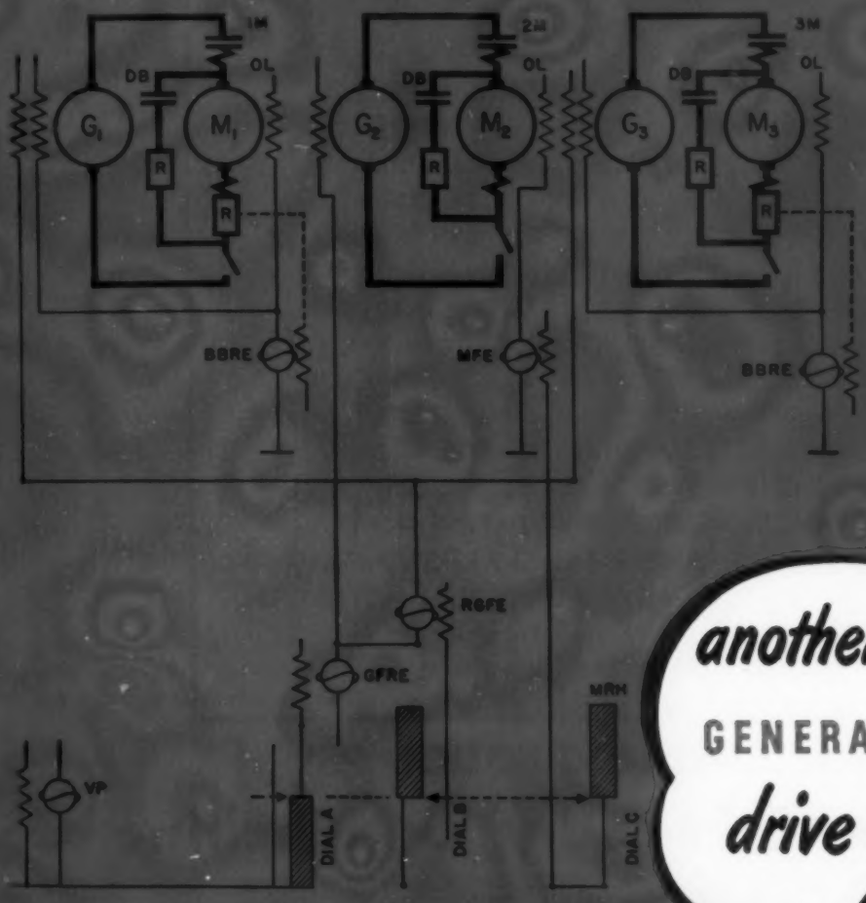
Accelerates and decelerates rapidly at a uniform, reliable rate from any speed, assuring accurate stopping between reversals, longer operation at top speed. Strip gets "on-gage" faster, stays "on-gage" longer!

It's one more example of General Electric's ability to handle *your* steel-mill drive problems successfully. Why not ask a G-E steel-mill specialist to discuss them with your engineers? *Apparatus Department, General Electric Company, Schenectady 5, N. Y.*

GENERAL ELECTRIC



Running the strip back and forth through this reversing mill, the G-E drive decelerates quickly for accurate stopping between reversals, longer full-speed operation at 1250 fpm.



HOW THIS MILL WORKS

Speed of the mill is set by the speed of the main motor (M_2). This speed is controlled by generator (G_2) voltage up to base speed. Voltage is regulated to a value set by the motor operated rheostat (MRH) through an amplidyne exciter (GFRE). Speeds above base speed are obtained through field weakening by adjusting the motor field exciter (MFE) voltage. The reel motors (M_1) and (M_3) stay synchronized with (M_2) at all times by pulling or dragging with substantially constant tension: This is assured by adjusting the voltage of the reel generators (G_1 and G_3) to a value proportional to the strip speed, through a combination of the output of the amplidyne (GFRE) and the reel generator field exciter (RGFE). The armature current of the reel motors (M_1) and (M_3) is controlled by an amplidyne (BBRE) which acts to buck or boost the shunt field.

another example of

GENERAL ELECTRIC

drive engineering at work!

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- COILER ROLLS
- TENSION ROLLS
- STEEL MILL ROLLS

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MORE TONS PER PASS

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SHEET SCRUBBER AND CLEANING LINES
HOT SAWS—ROCKING AND SLIDE TYPES
HOT BEDS—COOLING BEDS—TRANSFERS
BILLET EJECTORS—PINCH ROLL STANDS
SLITTERS—SPECIAL SHEARS AND GAUGES
TILTING TABLES—TRAVELING AND LIFTING TABLES
CONTINUOUS PICKLING LINES—ROLLER LEVELLERS
FURNACE CHARGING EQUIPMENT—FURNACE PUSHERS
STRIP STEEL COILERS AND REELS—SCRAP BALLERS
RAILROAD SPIKE FORMING MACHINES—ROLL LATHES
SHEET GALVANIZING LINES—WIRE PATENTING FRAMES
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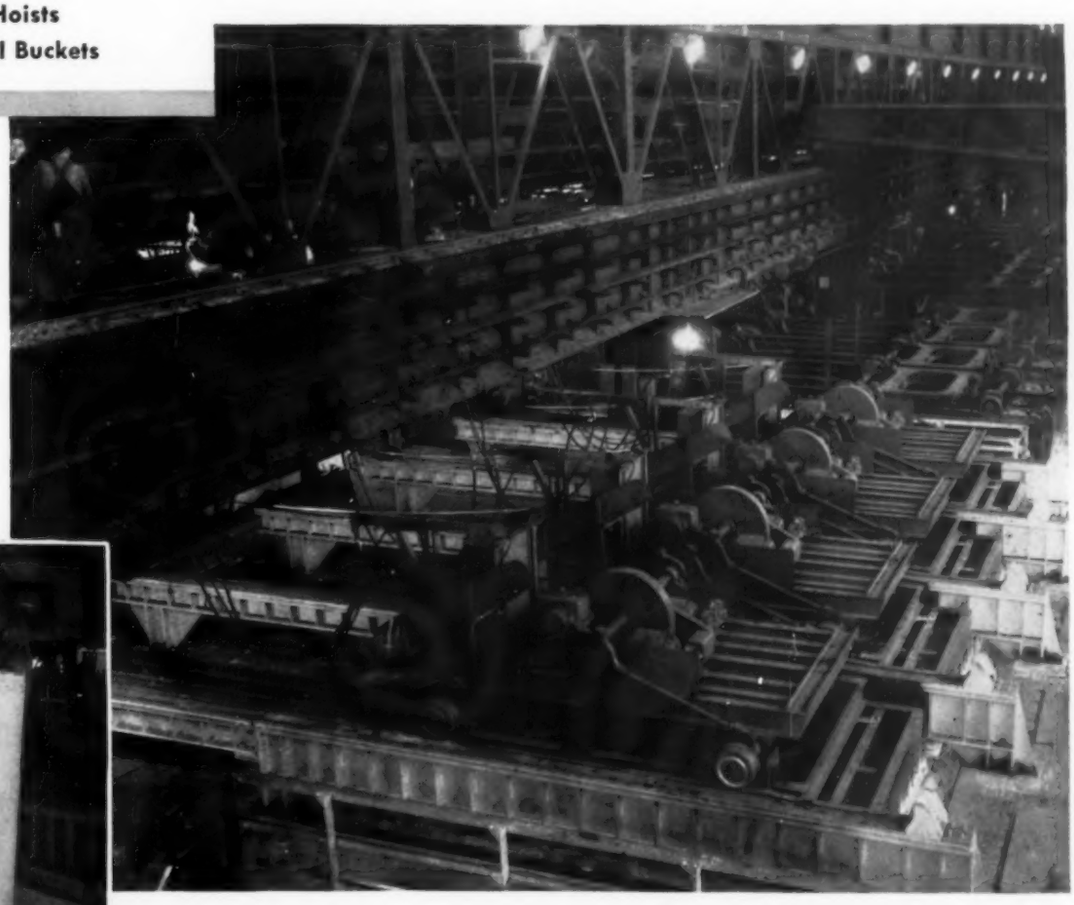

In this Wellman Two-Motor Carriage, one motor raises the cover and the other motor moves the carriage.

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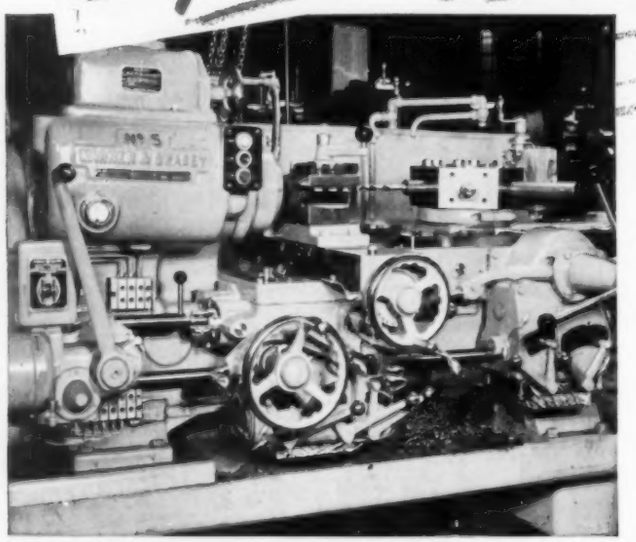

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Date-line Diary...

June 1

▲ Price of zinc advanced 1½¢ a lb to 14½¢ a lb in East St. Louis.

June 2

▲ CIO Steel Workers told Congress that they want the government to support the railway equipment business by setting production goals and purchasing the surplus cars which may become available.

June 3

▲ The basing point bill was passed by the Senate and sent to the White House for signature.

▲ Federal Judge Knox refused petition of the Justice Department to break up the Aluminum Co. of America in an anti-trust case started thirteen years ago.

June 4

▲ Department of Commerce reported that employment rose to 59,731,000 in May, a gain of 1,063,000 over April. Unemployment in May dropped to 3,057,000.

June 5

▲ Based on reports of companies having 94 per cent the capacity of the steel industry, production for the week beginning June 5 was 101.3 per cent of capacity. This is equivalent to 1,931,000 tons compared with 1,934,900 tons one week ago.

▲ No. 1 heavy melting scrap rose $4.00 to $46.00 a ton in the Pittsburgh District, a new record.

▲ Copper prices rose 2¢ to 22½¢ a lb.

June 6

▲ Secretary of Treasury Snyder stated that the government's deficit for the present fiscal year will be less than $5,000,000,000.

▲ Arthur B. Homer, president Bethlehem Steel Co., announced that they are embarking on a $32,000,000 expansion program at the Johnstown, Pa. plant.

June 7

▲ The Sharon Steel Corp. raised the price of sheet and strip from $3.00 - $7.00 a ton.

▲ It was estimated that American steel companies have contracted recently to buy as much as 200,000 tons of steel scrap from Europe at prices which are far below present U. S. market.

June 8

▲ The Aluminum Association reported that production of primary aluminum in April was about 116,000,000 lb. Shipments of sheet, strip and plate dropped about 21,000,000 lb from March to 90,800,000 lb in April.

▲ American Railway Car Institute reported that deliveries of freight cars in May were 2,193 compared with 971 in April and 9525 in May 1949. New orders during May totaled 11,636 giving a backlog as of June 1 of 42,300.

▲ Charles E. Wilson of General Motors Corp. announced that they will not raise automobile prices as a result of the new CIO contract.

▲ The Yoder Co. announced that they are going to form a subsidiary in France to run a new plant in Paris.

June 9

▲ The AISI announced that April employment in the iron and steel industry averaged 621,100. Payments to wage earners were $1.707 an hour compared with $1.697 in March for an average work week of 38.5 hrs. The total payroll in April was $186,185,000.

June 10

▲ According to Ward's automotive reports, automobile production will set a new record this week of 191,585.

June 11

▲ Securities and Exchange Commission and the Commerce Department reported that estimated expenditures for the first nine months of 1950 by American business for expanding plant and equipment is $12,710,000,000. This is greater than originally estimated.

June 12

▲ Based on companies having 94 per cent of capacity for the steel industry, production of iron and steel the week beginning June 12 is scheduled at 101.1 per cent of capacity. This is equivalent to 1,927,200 tons compared with 1,931,000 one week ago.

June 13

▲ The AISI reported that exports of iron and steel products in 1949 were 4,685,462 tons, a slight gain over 1948 but the second lowest for the past ten years. Shipments of pipe totaled 834,183 tons for a new record.

▲ The Kaiser Aluminum and Chemical Corp. announced that it will spend $1,000,000 this year to improve its aluminum cold rolling mill at Spokane, Wash.

▲ Zinc price rose ½¢ to 15¢ a lb.

June 15

▲ According to the F. W. Dodge Corp., construction contract awards for the 37 states east of the Rockies totaled $1,347,603,000 or down less than 1 per cent from the month of April.

▲ According to a survey by the Federal Reserve Board on consumer spending plans, U. S. consumers plan to keep up their heavy buying of durable goods during 1950.

June 16

▲ The Allis-Chalmers Manufacturing Co. and the CIO announced that a settlement had been made between them on the terms of a pension agreement.

▲ President Truman vetoed the freight absorption bill.

▲ The Labor Department estimated that new homes started in 1950 will total between 1,200,000 and 1,250,000.

June 17

▲ The AISI reported that total shipments of steel in April totaled 5,780,453 net tons, the highest in thirteen months. Shipments for the first four months of 1950 totaled 22,119,319 tons compared with 23,217,000 tons for the first four months of 1949.

June 18

▲ The Agricultural Department estimated that income of farmers from livestock and crop marketings in the first half of 1950 will be about $10,600,000,000 or 9 per cent below the first half of the previous year. Farmers prices are about 6 per cent below a year ago and volume is also lower.

▲ Based on reports from companies having 94 per cent of the steel capacity of the industry, the operating rate for the week beginning June 19 is scheduled at 101.2 per cent of capacity. This is equivalent to 1,929,100 tons compared with 1,927,200 tons one week ago.

June 20

▲ Carnegie-Illinois Steel Corp. purchased 100,000 tons of steel scrap from Germany.

June 21

▲ The directors of the Youngstown Sheet and Tube Co. issued a call for a meeting of shareholders for September 22 to consider a proposed increase in the number of common shares and to split the shares two for one. The quarterly common dividend was increased from $1.25 to $1.50.

▲ National Steel Corp. announced that they are embarking on a $25,000,000 to $30,000,000 expansion program which will add 500,000 tons to the annual capacity of the National Steel Corp. Program includes a new blast furnace and enlargement of open hearth furnaces.

▲ The ECA announced that they had approved purchase of $5,100,000 worth of equipment and materials for the Royal Dutch Blast Furnace and Steel Co. at Ijmuiden.

June 22

▲ The AISC reported that May bookings of fabricated structural steel were 183,373 tons and May shipments were 157,189 tons. The backlog for the next four months increased to 577,823 tons.

June 23

▲ C. E. Wilson, president of General Motors Corp. predicted motor vehicle production in the United States and Canada will total 8,000,000 units in 1950.

June 24

▲ Price of lead was cut ½¢ to 11½¢ in New York.

▲ Labor Department reports that employment rose 320,000 in May to a new high in 1950 of 43,200,000 in the mines, mills and factories. This is not total employment.

▲ The Federal Reserve Board predicts that the current business boom will last at least for the remainder of the year.

▲ Clifford S. Strike, president New England Steel Development Corp., reported that steel companies are not opposed to the erection of a steel company in New England if built by private capital. He did state, however, that the industry would be opposed if the government were to have an interest in the operation.

June 25

▲ Youngstown Sheet & Tube Co. is planning on building four open hearths at the Indiana Harbor Works to produce about 600,000 tons of ingots. When these furnaces are in operation, the company will discontinue its bessemer department.

▲ Five western railroads were struck by A.F.of L. switchmen. These included the Rock Island; Denver, Rio Grande & Western; the Chicago Great Western; the Western Pacific; and Great Northern. The union is after six days par for a five day week. This strike may affect iron ore shipments from the Mesabi Range.

▲ Communist North Korean forces invaded South Korea this morning.

June 26

▲ Stocks broke as a result of the Korean invasion and commodities moved somewhat higher.

▲ Secretary of Treasury Snyder predicted that the government's deficit for the fiscal year will not be more than $3,500,000,000. This is less than the previously predicted a few weeks ago.

▲ Based on reports of companies having 94 per cent of the steel capacity of the industry, the operating rate is scheduled at 101.2 per cent of capacity for the week beginning June 26. This is equivalent to 1,929,100 tons or the same as last week.

▲ The Justice Department filed a civil suit against the United Engineering and Foundry Co. of Pittsburgh charging that it had violated the Sherman Act by entering into unlawful cartel agreements. The company issued a formal statement denying violation of any laws.

June 27

▲ General Electric Co. offered a 3 per cent wage increase and expanded insurance and pension benefits to 130,000 employees.

June 28

▲ National Tube Co. announced an increase of about $6.00 per ton in its price of galvanized steel pipe. American Steel and Wire Co. announced increases in price of stainless steel, cold rolled strip, cold drawn wire and cold drawn bars of 1.5¢ per lb. The Carnegie-Illinois Steel Corp. increased price of some stainless steel products from 1 to 1½¢ per lb. The above increases were due to increases in the price of zinc and nickel.

▲ The price of lead dropped ½¢ to 11¢ a lb in New York.

▲ Electricity output last week set a new record of 6,102,000,000 kwhr.

▲ Carl W. Meyers announced that the Colorado Fuel and Iron Corp. is expanding and improving facilities in Buffalo for production of steel. Four open hearths will be adapted to the use of oxygen and two blast furnaces will be improved as well as the rod mill.

▲ The Great Lakes Carbon Corp. purchased the St. Louis coke plant of Laclede Gas Light Co.

June 29

▲ American Steel & Wire Co. announced that it will install the latest equipment for washing blast furnace gas in its steel works at Donora.

▲ The House approved the excise tax cutting bill reported by the Ways and Means Committee. Excise levies are reduced $1,010,000,000. Higher taxes will be levied on large corporations.

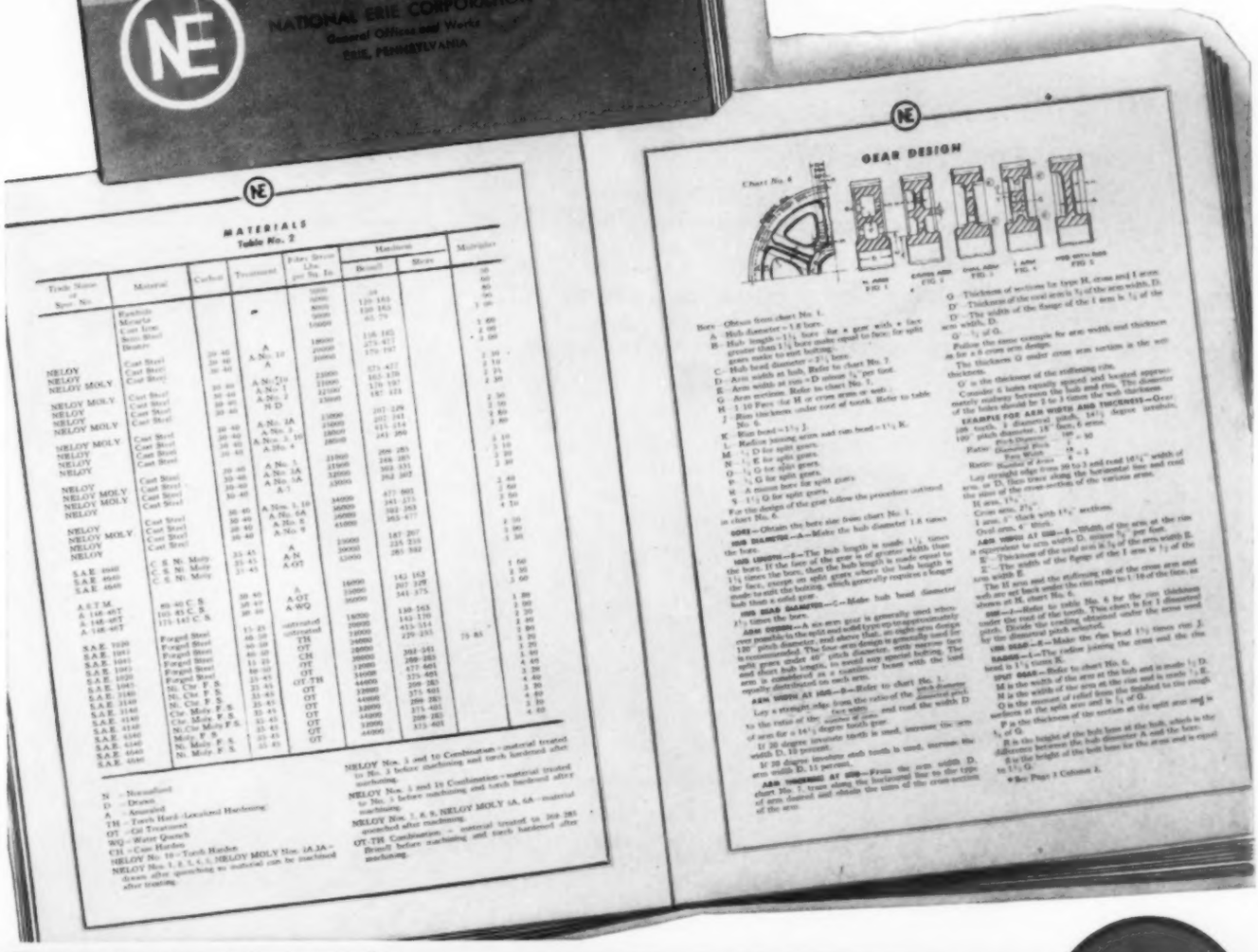
June 30

▲ National Tube Co. announced that it is putting back into production furnace No. 2 at McKeesport which has been shut down for 57 days. Furnace has capacity of 1000 tons a day.

▲ According to Ward's automotive reports, automobile production in the United States set a new record in June of 718,000 units.

A Book you need!

National Erie offers bulletin No. 3 1950 revised edition — a standard procedure in determining the size and horsepower capacities of gears of different materials. 24 pages of valuable engineering data. Yours for the asking!



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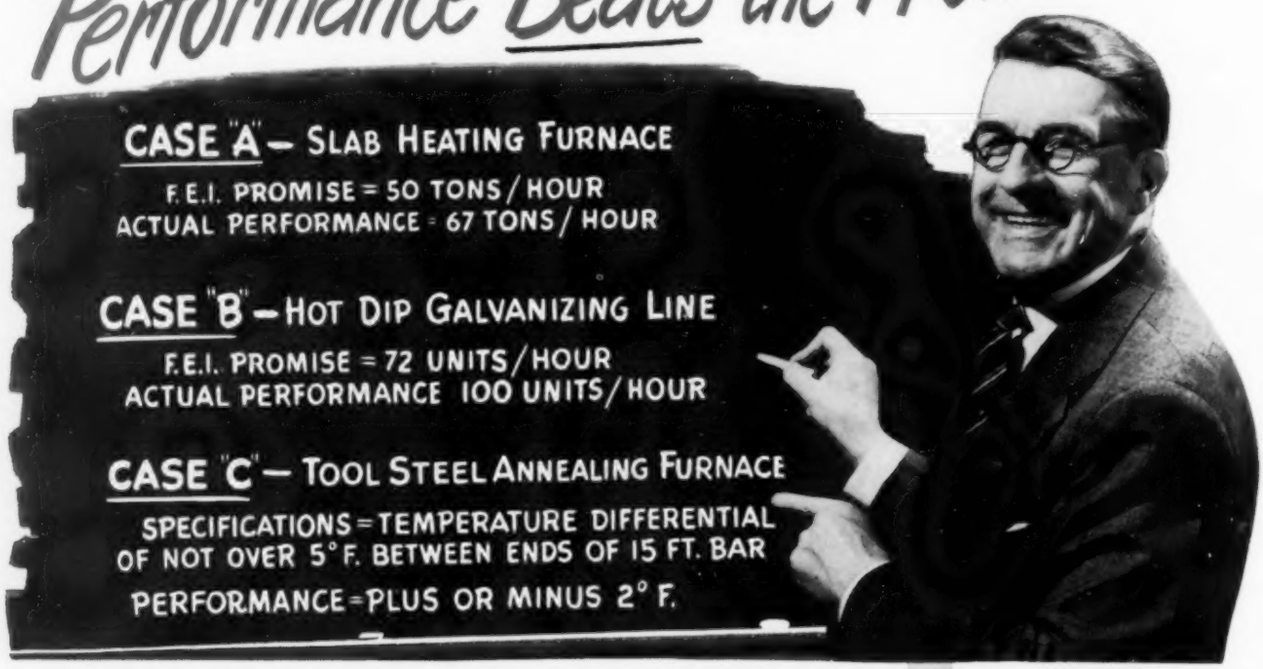
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ACTUAL PERFORMANCE = 67 TONS / HOUR
CASE "B" – HOT DIP GALVANIZING LINE
F.E.I. PROMISE = 72 UNITS / HOUR
ACTUAL PERFORMANCE 100 UNITS / HOUR
CASE "C" – TOOL STEEL ANNEALING FURNACE
SPECIFICATIONS = TEMPERATURE DIFFERENTIAL OF NOT OVER 5° F. BETWEEN ENDS OF 15 FT. BAR
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Results count and continued repeat business from successful steel companies is an indication of F.E.I. performance. You can depend on F.E.I. promises. Our staff of engineers includes men who have grown up with the steel industry ... from the days of crudest applications over 25 years ago, through all the evolutionary steps in steel making, to the improved techniques of today. Production has been increased over 20% in the past decade due to advanced heating methods, and Furnace Engineers knows how to meet today's rigid metallurgical requirements for quality and for faster, more economical production.

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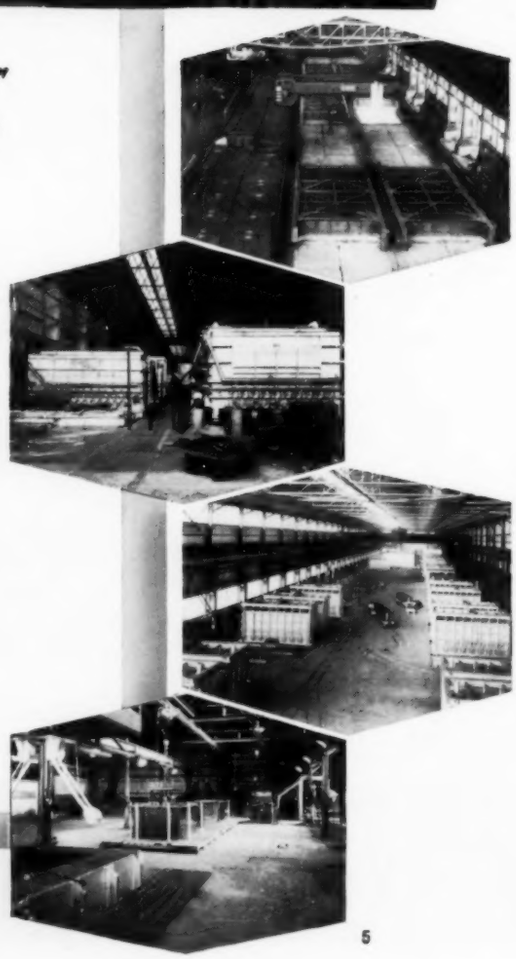

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5

Industry News...

MINE ROOF "PINNING" ELIMINATES UPRIGHT TIMBER SUPPORTS IN TCI MINE

▲ Another long step to increase the safety and convenience of underground miners is being taken by a subsidiary of United States Steel. By installing "pinned-up" mine roof supports, Tennessee Coal, Iron & Railroad Co. has cleared all upright timber supports from more than 5 million sq ft of its coal and iron ore mines.

This means that men who work anywhere in one big new coal mine, in parts of two others, and in seven or eight ore mines of TCI, no longer have to wrestle with big machines and haulage cars in narrow areas between posts erected to support the roof. Their movements are freer than ever before in underground operations of this kind.

The mine roof is literally "pinned" to solid rock above the working areas. As soon as miners have opened a space for working, holes are drilled through the overhead coal or ore and soft slate or shale to hard rock. In the holes, a slotted bolt of strong steel is wedged. The end of the bolt which projects below the roof level is threaded; on it is fastened by means of an ordinary steel nut a large square steel plate which is as effective in holding up the roof as an upright timber.

To date, there have been no accidents from fall of roof in either coal or iron ore mines directly caused by the new method of roof support. In fact, the frequency of accidents in TCI ore mines in 1949 was the lowest in the company's history, in the first eight months standing at 8.32, a reduction of 54 per cent from the same period in 1948.

Meantime, the quality of product has greatly improved. With the advent of the pinned-up roof, slate picked from the mine-run ore has declined from an average of 275 tons a week before the pinned-up roof was introduced, to practically zero. The real "pay-off," according to TCI engineers, has been a reduction of the acid content of conditioned ore by about 2 per cent.

In the ore mines which use the pinned-up roof there has been a distinct reduction in the cost of operation because the steel bolts and "shin plaster" plates are less expensive than big upright timbers. While costs in the coal mines have run a trifle higher, the increased efficiency has more than paid off in all places where mobile equipment is used for loading. Other benefits are improved ventilation due to freer air currents, better clearances hence less damage to equipment, less time required to hang cables, curtains, air lines and the like, as well as better mine "housekeeping."

The initial information which led United States Steel's southern subsidiary to try out this major improvement in mining practice came from the United States Bureau of Mines and the experience of one lead and one coal mine. Early in 1948, TCI engineers began testing the new system in its new Concord mine, which produces some 5,500 tons of coal a day. They soon were adding improvements of their own to the new roof-support system. Studies were made to develop the most economical high-strength bolt and the best method of anchoring it to solid rock, and to determine the best time and places to fasten the plates.

Good rivet-grade steel is used for the bolts. This provides a minimum ultimate strength of 56,000 psi, assuring that a 1-in. bolt will support 33,600 lb of roof on its threaded end and 44,000 lb on its anchored end. To develop a bolt design that would consistently provide anchorage strength sufficient to develop the full tensile strength of the bolt, tests were made on various designs and sizes of wedges, rods and holes. After installation, the test bolts were pulled by a hydraulic jack rig until they broke and the tensile strengths were noted.

The steel bolts used to support TCI mine roofs are of various lengths depending on use. The trend in coal mines is to use bolts long enough to penetrate the drawslate and anchor in the sandstone roof. Practice in the ore mines is to use bolts long enough

Holes are drilled through the overhead coal or ore and soft slate or shale to hard rock. In the holes a slotted bolt is wedged. An ordinary nut holds a large steel plate against the mine roof.

to anchor the roof in an arch formation, the entire arch anchored to the solid rock above it. In some cases, instead of plates, steel channels are fastened to the pins to hold up larger roof areas where clearance is provided.

REPUBLIC TO EXPAND CLEVELAND CAPACITY

▲ An expansion of steel-making capacity at its Cleveland district plant is planned by Republic Steel Corp. The plan contemplates increasing the heat size on all of the 15 open hearth furnaces to tap 220 tons per heat as compared with 200 tons at present. The contemplated expansion would not make any additional steel available before early 1951.

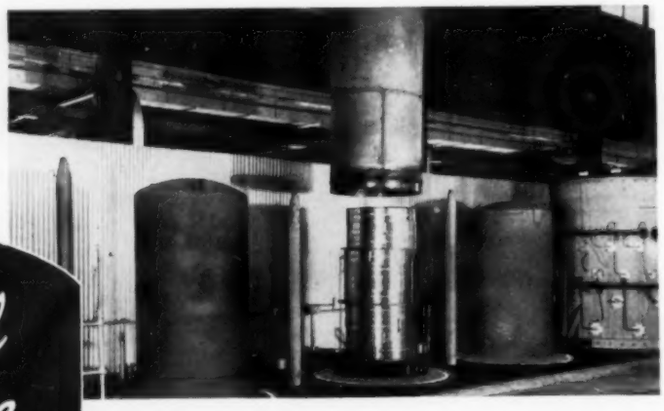
Beside the extensive work in rebuilding the furnaces, there will be major structural changes necessary in the huge open hearth building. Principal among these will involve strengthening columns which support crane runways on the pit side of the furnaces and strengthening other materials handling equipment.

ATLANTIC STEEL HOLDS OPEN HOUSE

Steel has a myriad of uses and applications, and one of them that is most important to the future of Southern agriculture was dramatically demonstrated at an open house and Southern Agricultural Implement Show staged by the Atlantic Steel Co. in Atlanta, Ga., May 5 and 6. This gigantic industrial pageant which bore the theme of "Dixisteel on Dixie Farms" began with visitors observing the making of raw steel in Atlantic's three 72-ton capacity open hearth furnaces and ended with exhibits displayed by 35 Southern manufacturers of farm implements, equipment and modern machinery.

EF

Bell Type FURNACES



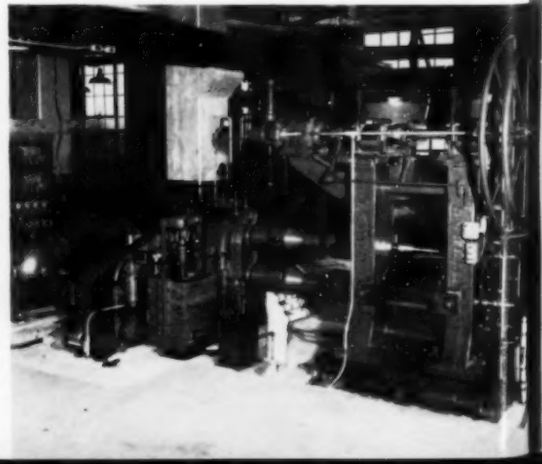
for annealing, carburizing, nitriding and other processes

EF Bell or Hood type furnaces may be used for a wide variety of products and processes—and the cycle readily changed to suit the process. The gas fired installation above bright anneals strip. Other fuel fired and electric units are available for normalizing rod, annealing wire, laminations and other products—for malleableizing, carburizing, nitriding and other processes. A single furnace serves several bases. Forced circulation assures rapid and uniform heating of the entire charge regardless of the weight, size, height or density of the load. We build batch or continuous furnaces for any heat treating requirement. We solicit *your* inquiries.

Gas-Fired, Oil-Fired EF and Electric Furnaces
for any Process, Product or Production
THE ELECTRIC FURNACE CO.
WILSON ST. at PENNA. R. R. Salem - Ohio

BUREAU OF STANDARDS TO DO ROLLING RESEARCH

▲ The recent installation of a new 2-high 16 x 24-in. rolling mill at the National Bureau of Standards is expected to facilitate greatly the preparation of metallurgical specimens for the Bureau's program of research on the structure, properties, and behavior of metals and alloys. The mill, which takes 4-in. ingots or plate and is equipped for both cold and hot rolling, will be employed in a wide variety of studies, such as the melting and casting of metals in vacuum, investigations of magnesium and aluminum alloys including the use of light metals for housing construction, and



work on the properties of ferrous metals including stainless steel. It will also be used for service operations for other government agencies engaged in metallurgical work which do not have facilities for rolling.

A feature of the new rolling mill is a pair of internally steam-heated rolls, which will permit such work as the rolling of magnesium alloys in a temperature range of 400 to 600 F. Provision is made for raising and lowering the rolls electrically without the necessity of manual adjustment. A hydraulic system, which provides support for the roll bearings, makes the changing of rolls a relatively simple operation.

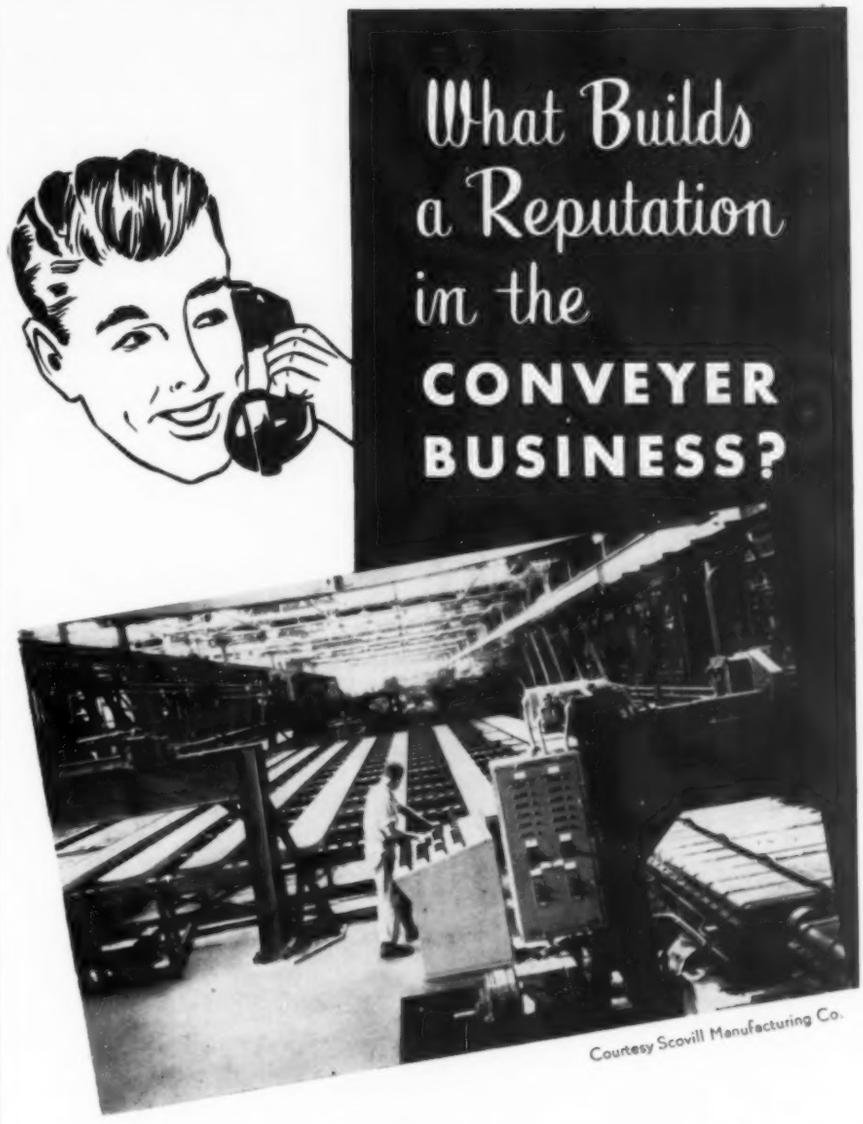
Important changes have also been made in the Bureau's foundry, which now has one 650-lb tilting furnace, one 300-lb tilting furnace, one 200-lb lift-coil furnace, and one 100-lb vacuum furnace. A separate fireproof, dustproof room houses two new sets of capacitors, and the single generator previously used has been replaced by two new 250-kw units. This permits simultaneous operation of two furnaces independently, with a consequent saving in the over-all time required for heats.

DE LAVAL SEPARATOR TO MOVE OFFICES

▲ De Laval Separator Co. has revealed that plans have been completed to move the De Laval executive staff and general office from New York City to Poughkeepsie, N. Y. Construction has been started on a new, attractive and ultra-modern De Laval general office building which will be located a short distance from the De Laval factory.

This is an interesting and significant move because the De Laval general office has been located in New York since 1883 and at 165 Broadway for more than 40 years. As a matter of fact, De Laval was among the first two or three tenants to occupy offices in the then partially completed City Investment Building, one of New York's first skyscrapers.

However, a small executive and financial office with sales conference rooms will be maintained in New York, probably in the midtown area. De Laval's new general office building at Poughkeepsie will probably be ready for occupancy late next summer.



It's experience that builds a reputation in the conveyer business—and only years of dealing with thousands of conveying problems can provide it. The lessons learned along the way—the good jobs—the difficult ones—those that weren't so good—the equipment that was too light, or heavier than it needed to be—all go to make up a seasoned, well-balanced materials handling organization—people that can give a dependable conveyer service to both light and heavy industry.

Mathews Engineers have been dealing with conveying problems for nearly 50 years. They have the stuff of which reputations are made—good, solid experience. There is no substitute for it.

The benefit of this experience, and the facilities of three modern plants are available to American and Canadian Industry. Your handling problem is our business. Your Mathews Engineer would like to tell you about Mathews Conveyer Systems, and the smooth, continuous flow of materials which they create.

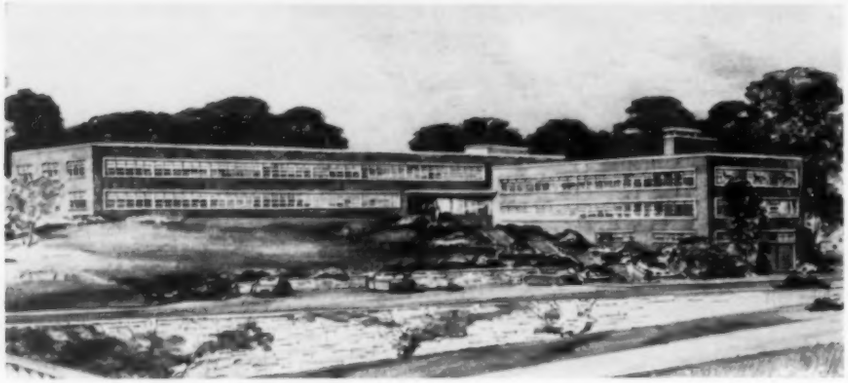
MATHEWS CONVEYERS

GENERAL OFFICES . . . . . *Mathews Conveyer Company*
ELLWOOD CITY, PENNSYLVANIA

PACIFIC COAST DIVISION . . *Mathews Conveyer Company West Coast*
SAN CARLOS, CALIFORNIA

CANADIAN DIVISION . . . . . *Mathews Conveyer Company, Ltd.*
PORT HOPE, ONTARIO

Engineering Offices or Sales Agencies in Principal American and Canadian Cities



The new office buildings will be ready for occupancy in summer of 1951.

The new general office building will be one of the finest in the Poughkeepsie area. It will be of brick and fireproof construction containing approximately 40,000 sq ft. The building site is high on a hill approximately two blocks back from the factory which is located on the Hudson River. The grounds are wooded and the best of the trees will be kept with the surrounding lawns attractively landscaped. From its windows one will look out upon a beautiful panorama of the Hudson, the wooded hills beyond, and in the distance the high Catskills.

The entire building will be air-conditioned and in addition to streamlined offices and the most modern office equipment available, it will contain a cafeteria and an auditorium for meetings, sales training, the showing of movies and other purposes.

SHEET AND TUBE BUILDS NEW OPEN HEARTHS

▲ Youngstown Sheet and Tube Co. plans to build four new open hearth furnaces and other facilities at its Indiana Harbor plant at East Chicago, Ind. The new furnaces, with necessary facilities, will produce 550,000 to 600,000 tons of ingots per year.

After these furnaces are in operation, the bessemer department at Indiana Harbor will be discontinued. As this produces about 300,000 tons of steel ingots per year, the net increase at Indiana Harbor will be 250,000 to 300,000 tons.

A new roll shop will be erected at the Indiana Harbor strip mill and finishing facilities will be added for hot rolled sheets and strip.

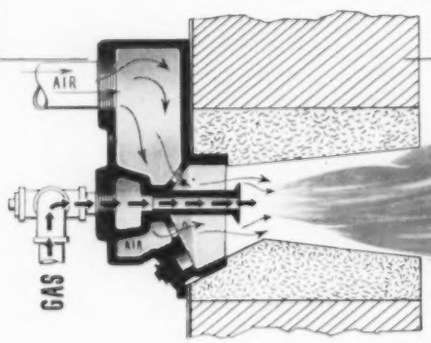
With present ingot capacity of 4,082,000 tons, these additions and other changes and improvements already made, will give the company an estimated ingot capacity of 4,500,000 tons.

TWENTY MILLS KEPT BUSY REROLLING RAIL

▲ Transforming old railroad rails into useful products, such as fence posts, bedsteads, clothes poles, wheelbarrow handles and playground equipment, keeps about 20 mills busy in the United States and Canada, says American Iron and Steel Institute.

GET MORE from your furnace!
MORE from your fuel!

BLOOM BURNER
TEMPERED-FLAME

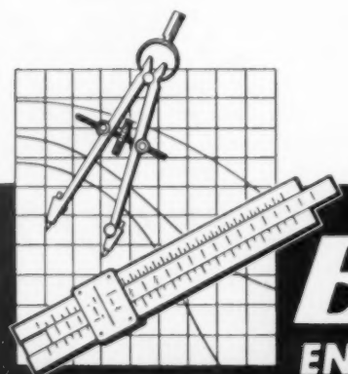


GREATER *Flexibility*—Furnace temperatures as low as 400° F. or as high as 2450° F. can be obtained and maintained without difficulty. The Tempered Flame Burner will light at full capacity, and will burn as long as it has fuel.

UNIFORM *Temperature*—With this Bloom burner, the desired temperature can be readily maintained uniformly throughout the furnace chamber.

FASTER *Heating*—Accomplished because cold spots are eliminated. Thus the time of annealing cycles is reduced.

Write for bulletin giving full details of the Bloom Tempered Flame Burner.



BLOOM
ENGINEERING CO., INC.
857 W. North Avenue Pittsburgh 33, Pa.

The old rails are not remelted. They are heated to rolling temperature in a furnace and then are sliced into three parts—the head of the rail; the web, namely the middle part of the rail; and the flange or base of the rail. Each of these sections is then rolled to the required size and shape.

Concrete reinforcing bars, structural tubing and light rails are the principal products rolled. Part of the glider on the back porch may once have been a rail carrying streamlined trains.

About 700,000 tons of finished product, mostly bars, are rolled each year from old material such as rails, axles and other products suitable for conversion by hot rolling without remelting. Rails have been used as a source of material for rerolling since about 1860.

TWO COKE BATTERIES SCHEDULED AT CLAIRTON

▲ Construction of two new coke batteries of 87 ovens each at Clairton, Pa., works of Carnegie-Illinois Steel Corp., replacing two batteries of old ovens, has been scheduled. Contract for the work has been awarded Koppers Co., Inc., it was announced.

Actual construction of the first new battery is expected to get underway early in September, with work on the second starting about 60 days later. The batteries are scheduled to go into operation about one year after the start of construction work.

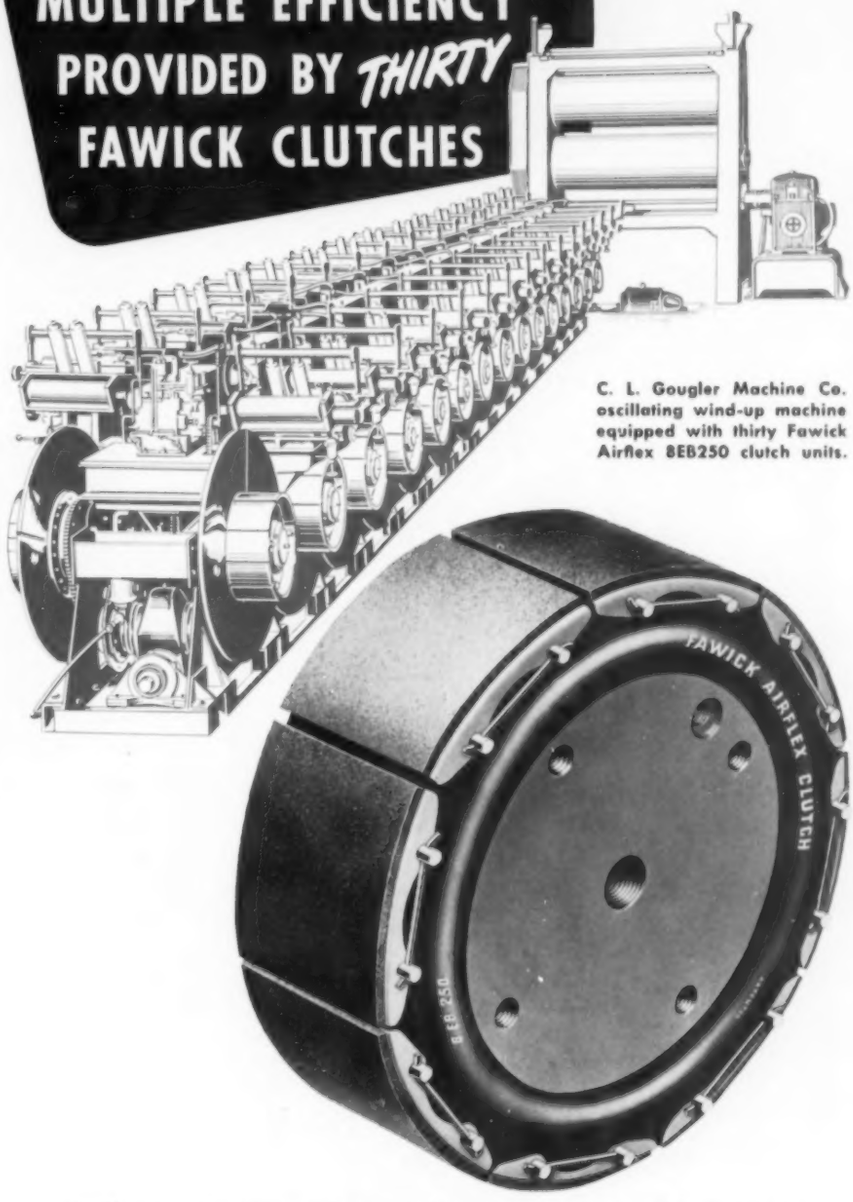
The new by-product ovens will be of the underjet type, designed for coke-oven gas heating, with recirculation of waste gases. The batteries will carbonize 5000 tons of coal every 24 hours, yielding approximately 3300 tons of coke in the same period.

Clairton works contains 1567 ovens which recover chemicals and gas during the coking of coal.

NATIONAL STEEL TO INCREASE INGOT CAPACITY

▲ Plans have been announced for an expansion of blast furnace, coke, and open hearth furnace facilities which will result in an increase of 500,000 tons per year in the ingot capacity of National Steel Corp. It is estimated that the total cost of the program will range between $25,000,000 and $30,000,000.

MULTIPLE EFFICIENCY PROVIDED BY *THIRTY* FAWICK CLUTCHES



C. L. Gougler Machine Co. oscillating wind-up machine equipped with thirty Fawick Airflex 8EB250 clutch units.

● This oscillating wind-up machine, capable of handling thirty separate coils simultaneously, demonstrates the high-efficiency operation of Fawick Airflex Clutches for strip or wire coil winder use.

The simple rugged design and construction of Fawick Clutches make possible (1) sensitive remote operating control of each coil; (2) desired tension control and accurate coil formation through variation in applied air pressure; (3) long, maintenance-free service.

On this installation as on many others, Fawick Clutches make good machines perform better.

For specific information on all advantages of Fawick Clutch and Brake units, write to the Main Office, Cleveland, Ohio, for Bulletin 300.

All desirable clutch characteristics are built into Fawick Airflex units

FAWICK Airflex CO., INC.
9919 CLINTON ROAD CLEVELAND 11, OHIO

FAWICK CLUTCHES = AXIAL CONTACT + 360° RADIAL CONTACT + SHOCK ABSORPTION + CONTROLLED TORQUE = PEAK EFFICIENCY

The present ingot capacity of National Steel Corp., fifth largest steel company in the United States, is 4,500,000 tons per year. When the expansion program is completed, National's annual ingot capacity will be increased to 5,000,000 tons.

Principal feature of the program will be the construction of a new blast furnace with a capacity of 40,000 tons of pig iron per month at a plant of Great Lakes Steel Corp., division of National Steel.

The new furnace will be an addition to the present blast furnace plant of Great Lakes Steel which consists of three furnaces of approximately similar size located on Zug Island in the Detroit River near Detroit, Mich. The coke plant at the same location also will be expanded to provide for the additional fuel requirement which will result from construction of the new furnace.

The output of pig iron from the new furnace will make possible a substantial increase in the production of steel at the Ecorse, Mich., plant of Great Lakes Steel Corp. He added that a further increase in steel production will result from the rebuilding and enlargement of an open hearth furnace at the Ecorse plant to a capacity of 500 tons per heat.

The expansion program also includes the rebuilding and enlargement of existing open hearth furnaces at the Weirton, W. Va., plant of Weirton Steel Co., another division of National Steel Corp.

The new blast furnace is expected to be placed in operation by January 1, 1952. Engineering work has been underway for some time, and field construction will start in the near future.

HAYS
CAN SHOW
YOU
HOW...
HAYS
INSTRUMENTS AND
CONTROLLERS FOR
HEAT TREATING FURNACES
Indicating · Recording · Controlling
INSTRUMENTS
AND
CONTROLS
FOR EVERY
NEED
TO IMPROVE
MANY PHASES OF
STEEL PROCESSING...
AND TO CUT YOUR
FUEL AND LABOR COSTS.
The bulletin illustrated is not just a piece of sales literature but a complete 24 page treatise on the instrumentation and automatic control of steel making and heat treating furnaces. You'll want a copy for your reference files, want to profit from its practical, authoritative information.
And remember as you read it, Hays engineers are thoroughly qualified and ready to work hand-in-hand with you in solving your own specific instrumentation and control problems . . . without obligation.
Write for your copy today . . . Ask for Bulletin No. 48-750 (covering heat-treating furnaces). Companion edition covering open-hearth furnaces will also be included.
THE HAYS CORPORATION, MICHIGAN CITY 13, INDIANA
Steel that's better, with more uniform grain structure . . . maximum production because of continuous equipment performance . . . fewer rejects . . . lower fuel, maintenance and labor costs—these are advantages you can count on when you use Hays instruments and controls for:
Annealing
Brazing
Colorizing
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Cyaniding
Enameling
Glazing
Hardening
Heating
Heat treating
Melting
Nitriting
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For indicating and controlling:
Pressure
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Inquiries invited on any of these specific applications.
The HAYS CORPORATION
Since 1901
COMBUSTION & INDUSTRIAL INSTRUMENTS & CONTROL
MICHIGAN CITY, INDIANA, U.S.A

WESTINGHOUSE BUILDS M&R PLANT IN SOUTH

▲ Because of the increasing industrial importance of the South—and especially Birmingham, Ala., region—Westinghouse Electric Corp. will build a new plant in Birmingham, Ala.

The new plant will be operated by the Westinghouse manufacturing and repair department. It will provide extensive overhaul and repair facilities to serve customers in all parts of Alabama.

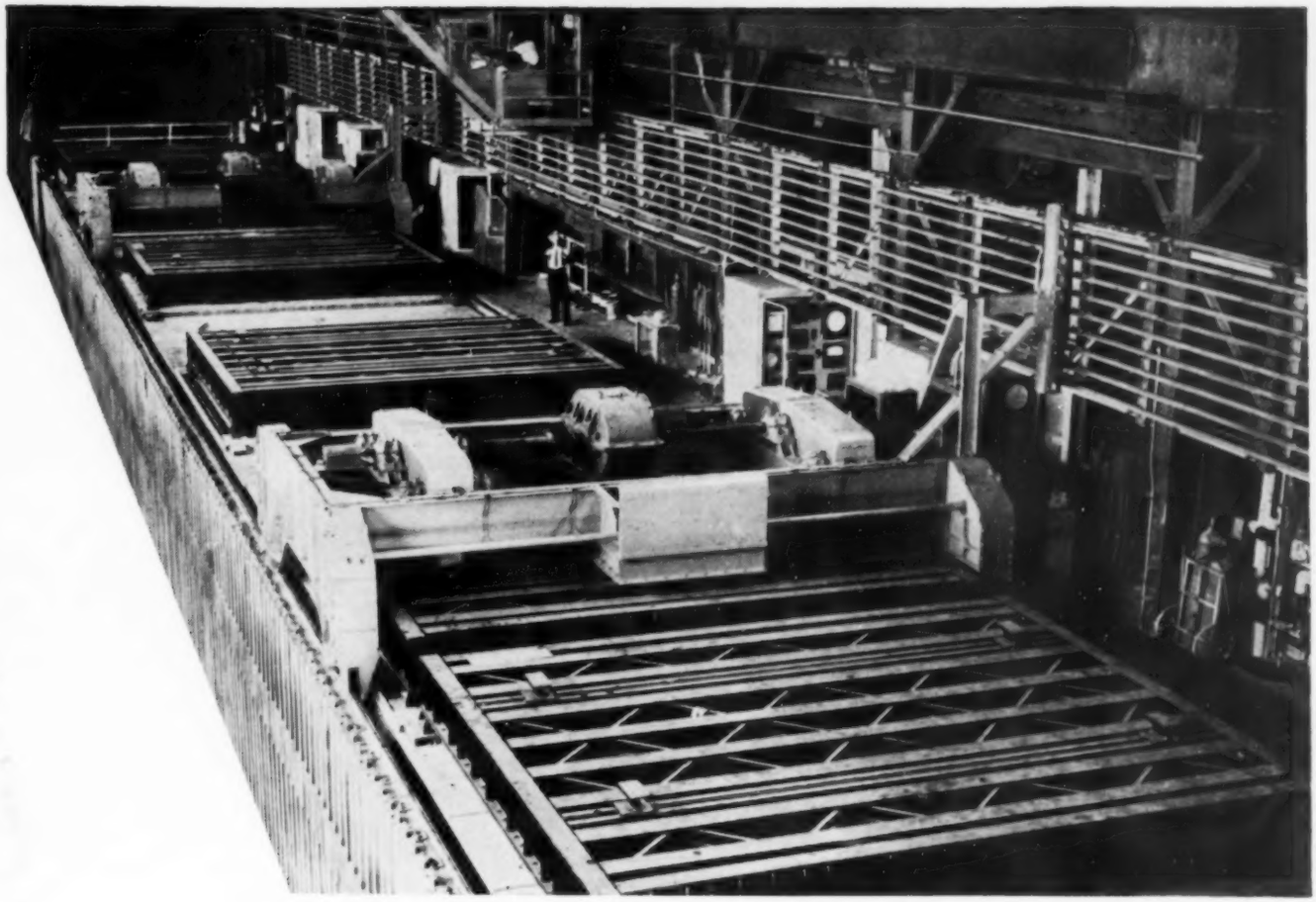
A site already has been secured for the new plant. A tract of land 400 ft long and 300 ft deep has been purchased on Third Avenue, South, between 33rd and 34th Streets, about one mile east of downtown Birmingham. The location is on a siding of the Southern Railroad, and on the main highway route to Atlanta.

SAFETY RESEARCH LAB DEDICATED JUNE 14

▲ The world's largest research laboratory devoted to the development of safety equipment for all industries was dedicated June 14 by the Mine Safety Appliances Co., Pittsburgh, Pa.

Principal speaker at the ceremonies was Ned H. Dearborn, president of the National Safety Council, who hailed the opening of the laboratory as one of the most significant advancements in the history of this country's industrial safety movement.

The company displayed its entire line of safety equipment, hundreds of products ranging from tiny first aid kits to a complete mobile laboratory for air pollution surveys.



Soaking Pits by Amsler Morton, with L & N Integrated Control; for uniform heating of ingots at both bottoms and tops; for scale control; for no "washing"; minimum fuel; long refractory life; ability to hold ingots in condition until needed.

Integrated Control Helps Mills Get Well-Heated Steel

NEW FOLDER

Only 4 Pages — But Important to Cost-Conscious Executives!

WELL-HEATED STEEL — whether it's ingots, slabs, bars, blooms or forging stock — is steel at the right temperature, with the right surface, ready for processing at the right time. It's the kind of steel that the mill gets from good furnaces, operated by good men, with the best instrumentation to help.

Right now, when costs are high, here is welcome news about instrumentation which is helping to get well-heated steel *at lower cost*. This instrumentation is Integrated Control . . . L&N's newest means for regulating large furnaces.

An Integrated Control panel looks very much like any other panel for centralized automatic control, except that it includes an additional "key" instrument . . . the new L & N Fuel-Air Ratio Controller. This instrument adds to the panel a combustion control which matches your L&N Temperature Control in sensitivity and dependability; is designed specifically by L&N, to go with its companion L&N equipment. As a result, Integrated Control brings closer-stepping coordination between furnace atmosphere, uniform temperature and correct draft; it helps mills get well-heated steel by efficient, economical operation. For folder, write Leeds & Northrup Company.

LEEDS & NORTHRUP COMPANY, 4942 STENTON AVE., PHILA. 44, PA.

LEEDS & NORTHRUP

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

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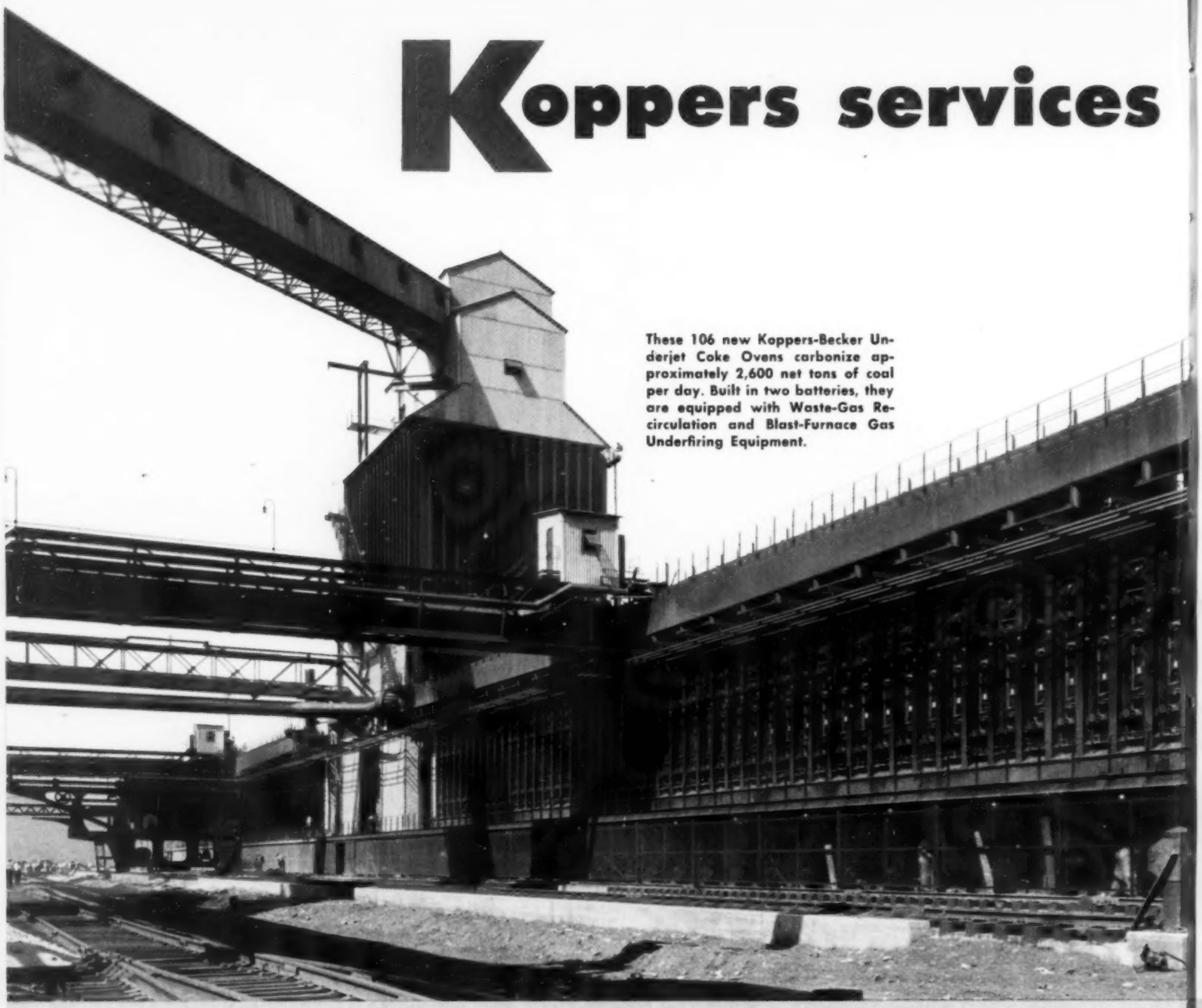
Koppers services



These 106 new Koppers-Becker Underjet Coke Ovens carbonize approximately 2,600 net tons of coal per day. Built in two batteries, they are equipped with Waste-Gas Recirculation and Blast-Furnace Gas Underfiring Equipment.

This plant was constructed by Koppers for the recovery of ammonium sulphate, tar, light oil and pure benzol products from the carbonizing of 1,050 tons of coal daily.

Freyn-Designed Structural Mill and Traveling Tilting Tables.

for the steel industry...

KOPPERS Company and its subsidiary, Freyn Engineering Company, offer comprehensive engineering and construction services to all branches of the iron and steel industry.

Freyn Engineering Company: Specialists in the design and construction of blast furnaces, open-hearth furnaces and sintering plants . . . in the engineering of mills, power plants and other steel plant facilities.

Koppers Engineering and Construction Division: Specialists in the design and construction of coke oven plants, auxiliaries and coal chemicals plants.

The installations pictured here give some indication of the scope of Koppers Metallurgical Engineering and Construction Services. Our Engineers and Management welcome the opportunity to consult with you.

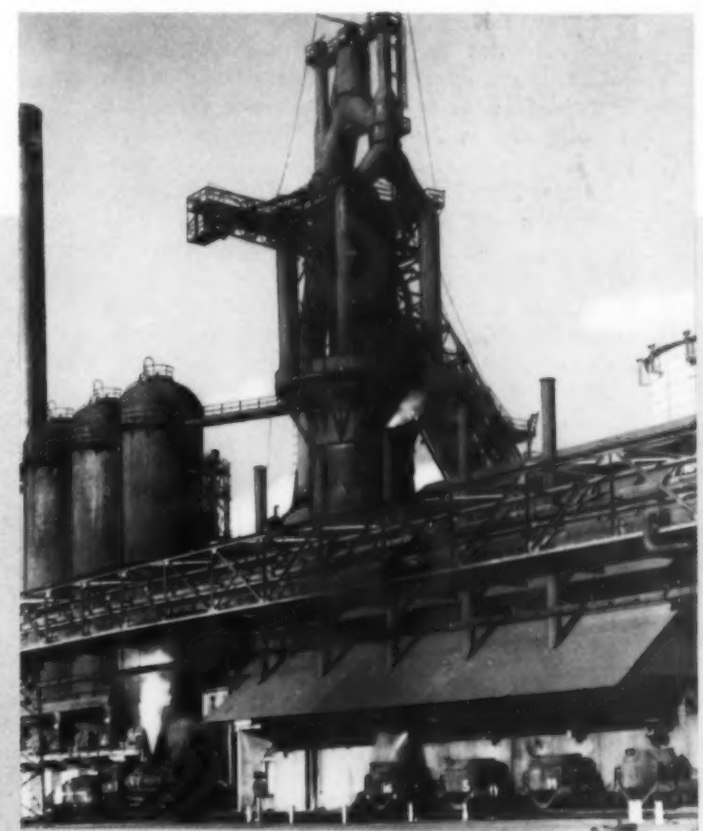
KOPPERS COMPANY, INC.

ENGINEERING AND CONSTRUCTION DIVISION

Pittsburgh 19, Pa.

KOPPERS

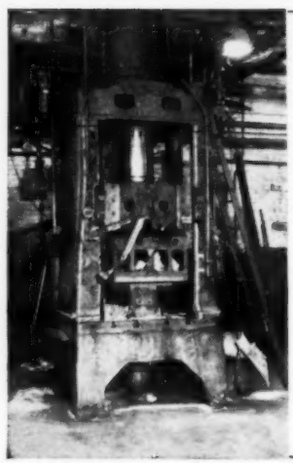
Freyn-Designed and Constructed Open-Hearth Furnaces.



Typical Freyn-Design Blast Furnace.

MOLTEN METAL won't affect LUMNITE* heat-resistant floors . . .

WHEN 2800°F. molten metal occasionally spills from lift-truck ladles onto this foundry floor, Lumnite heat-resistant concrete withstands the thermal shock. The 1750-sq.-ft. floor is constructed with a 5¼-inch-thick slab of Lumnite-trap rock heat-resistant concrete and a ¾-inch topping of tough, wear- *and* heat-resisting Lumnite-emery concrete. This Lumnite heat-resistant concrete floor made possible a change-over from dirt floors . . . permitted handling ladles with lift-trucks. Such concrete floors made with Lumnite calcium-aluminate cement may be quickly and easily installed with a minimum of outage time, because Lumnite concrete reaches service strength in 24 hours or less. For further information write to Lumnite Division, Universal Atlas Cement Company (United States Steel Corporation Subsidiary), Chrysler Building, New York 17, New York.



Time Saved, Cost Cut

in installing the bed for this 300 ton hydraulic press. Bed is 8′ by 8′ by 1½′ thick. The press was moved, foundation dug out of dirt floor, new foundation poured with Lumnite and ordinary concrete aggregate bed, and the press put back in place in less than 24 hours! Time off the job was kept to bare minimum. And maintenance costs are next to nothing for durable Lumnite concrete.

◀ *Heat-resistant floor and hydraulic press bed at Minneapolis-Moline Co., Hopkins Plant, Minneapolis, Minn.*

SPECIFY CASTABLE REFRACTORIES MADE WITH LUMNITE

**"LUMNITE" is the registered trade mark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.*

15-L-24

NBC SUMMER SYMPHONY CONCERTS—*Sponsored by U. S. Steel Subsidiaries—Sunday Evenings—June to September*

Owner? Boss? Employee?

If you're connected with a rolling mill your economic future depends on your methods and equipment.

In 62 years Morgan has built 198 mills of various kinds . . . each designed to dominate its particular market.

Undoubtedly the 5 Morgan mills now under construction will continue to provide the cost margin that gives the edge in competitive selling.

MORGAN CONSTRUCTION CO.
WORCESTER, MASSACHUSETTS
English Representative: International Construction Company
56 Kingsway, London, W.C. 2, England

RM-28

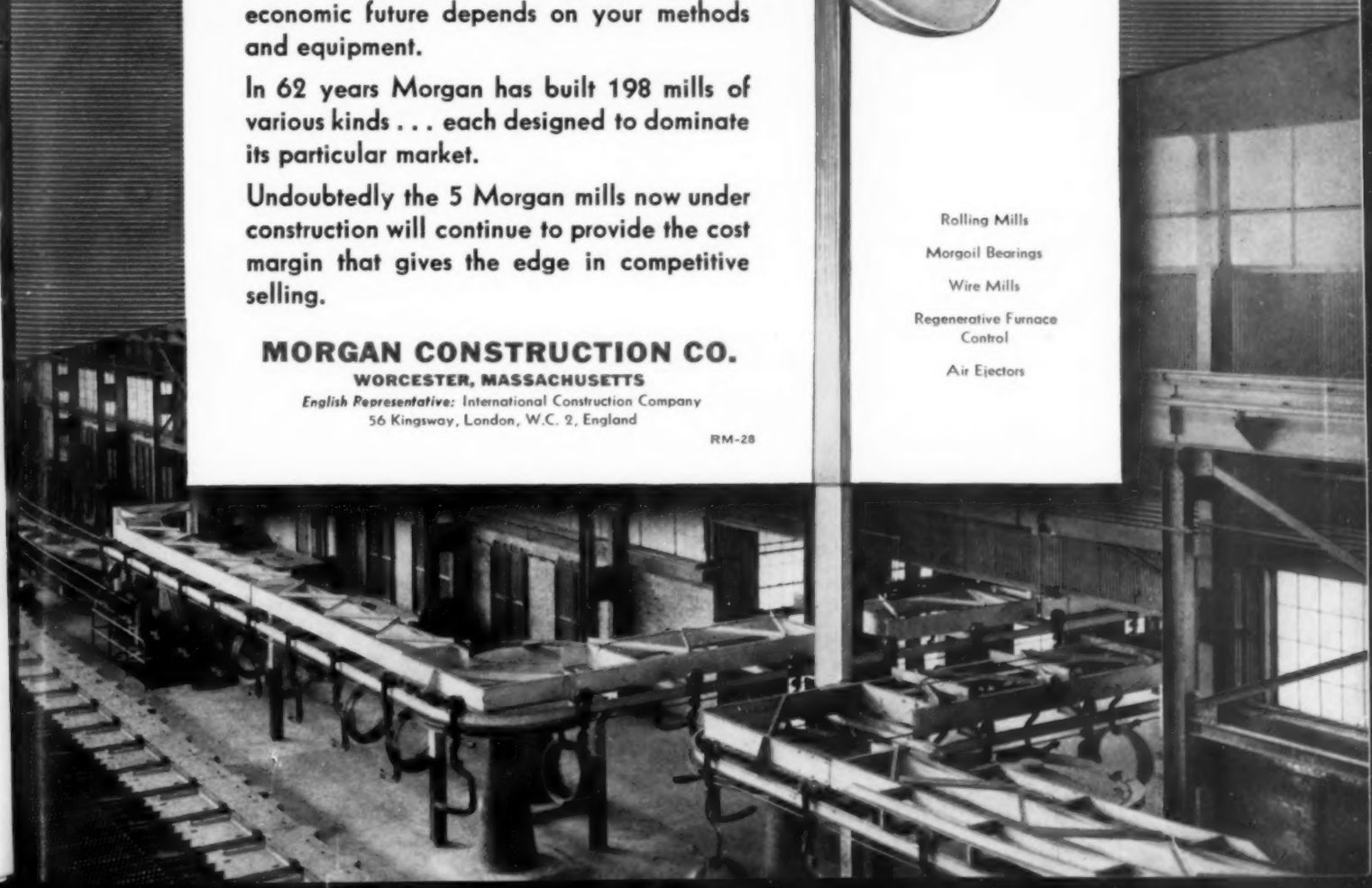
Rolling Mills

Morgoil Bearings

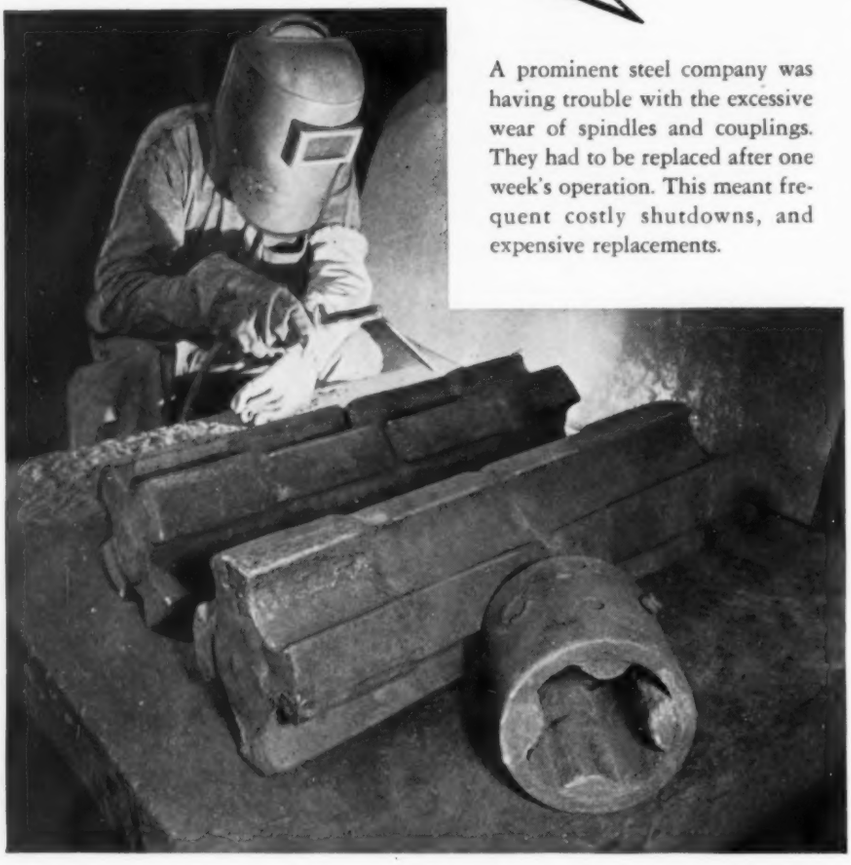
Wire Mills

Regenerative Furnace Control

Air Ejectors



HARDFACING lengthens equipment life in steel mill... cuts "down" time... saves money



A prominent steel company was having trouble with the excessive wear of spindles and couplings. They had to be replaced after one week's operation. This meant frequent costly shutdowns, and expensive replacements.

J. J. Barry, Airco Technical Sales Service Specialist, was called in. He suggested hardfacing these parts with Airco No. 91 alloy. Service life of the spindles and couplings jumped to six weeks—a 600% increase in lasting power, with great parts-replacement savings and fewer shutdowns.

The mill was extremely pleased with these results and carried the economies of hardfacing to a wide range of steel mill equipment—roller guides, side mill guides, open hearth charging peels, sintering plant pug mill blades, dies, and hundreds of other similar parts... Airco's new line of Hardfacing Alloys were used throughout, and all produced savings that ran all the way from "highly satisfactory" to "amazing."

For more information about the reduced costs, increased efficiency, and steadier production made possible by hardfacing steel mill equipment, write your nearest Airco office. Ask them for your free copy of folder ADR-64: "Hardfacing Applications in the Steel Industry."

AIRCO AIR REDUCTION

Offices in Principal Cities

TECHNICAL SALES SERVICE—ANOTHER AIRCO PLUS-VALUE FOR CUSTOMERS

More news about AIRCO steel mill processes

ACETYLENE SMOKING ELIMINATES HYDROGEN TRACES ON STEEL SURFACE

A leading steel mill, after experimenting on more than 2,000 molds of various sizes, plans to use acetylene ingot mold smoking in all molds that will be used for the pouring of "Tool Steels", "Electric Furnace Steel", "Acid Open Hearth Steel", and "Roll Foundry Steel". They claim that steel poured in molds—*and treated in any other way than by acetylene smoking,* show traces of hydrogen in the surface of the steel.

THE ECONOMICAL WAY TO CUT HEAVY SCRAP TO CHARGING BOX SIZE

Today, Airco offers steel men outstanding oxyacetylene cutting methods for easy and economical handling of heavy scrap. Practically any heavy scrapping job can be handled . . . regardless of size, shape or location . . . with:

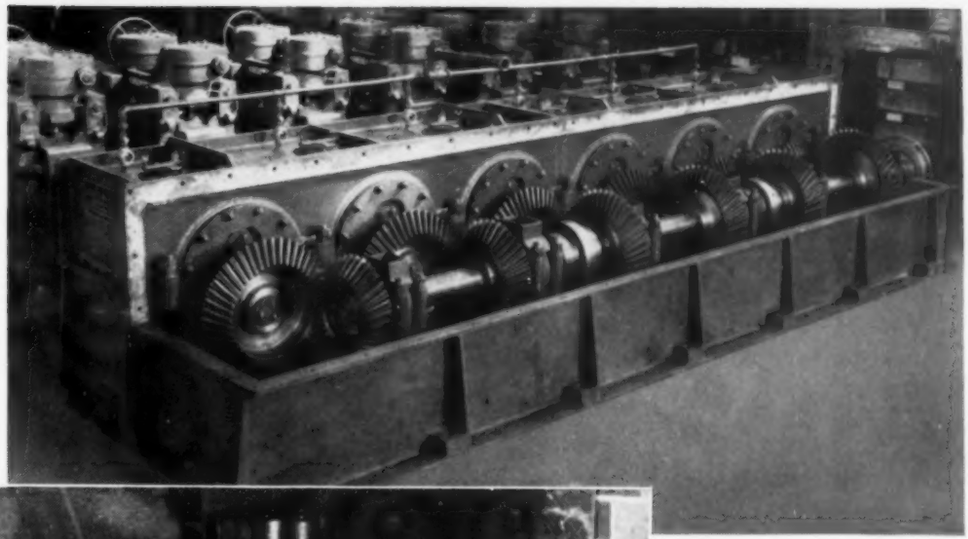
- **the oxyacetylene torch, plus oxygen lance.** Buttons, ingots, and similar large chunks can be cut to size in any position without initial handling.
- **machine gas cutting.** Where crane facilities are available, this set-up is ideal. All it requires is a heavy-duty cutting torch mounted on a standard Airco No. 40 Radiagraph or a Travograph.
- **the oxygen lance.** Where extremely large sections, such as open hearth spills and huge ingots are to be cut, the oxygen lance should be used.

All this is just another example of how modern Airco oxyacetylene equipment is helping steel mills slash time and costs.

★ ★ ★

Air Reduction supplies Oxygen, Acetylene and other industrial gases . . . Calcium Carbide . . . and a complete line of gas cutting machines, gas welding apparatus and supplies, plus arc welders, electrodes and accessories. Ask us about anything pertaining to gas welding and cutting, and arc welding . . . we'll be glad to help you.

10″ Continuous rod mill
Combination drive

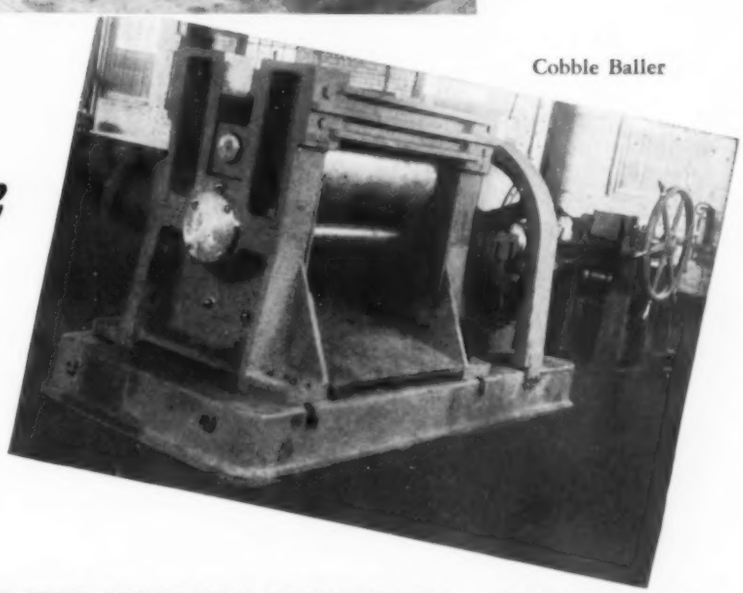


Double Oval Repeater

Help Yourself to Birdsboro's Experience

Almost 50 years of it devoted to research, design and advanced engineering contribute to the technical know-how necessary to provide you with maximum economies in the construction and operation of steel mill equipment.

Cobble Baller



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BIRDSBORO
STEEL MILL MACHINERY

MM-8-50

OFFICES IN:
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DESIGNERS AND BUILDERS OF: Steel Mill Machinery • Hydraulic Presses • Rolls • Special Machinery • Steel Castings • Crushing Machinery

. . . when you use "NATIONAL" Graphite Stool Inserts

● *It is impossible for molten metal to stick to graphite under any conditions.* This means that an ingot cannot possibly stick to a graphite stool insert. If you are bothered with stickers, equip your stools with "National" graphite stool inserts.

Think of the savings!

No lost time in freeing stuck ingots. Keeps maintenance costs down. For complete information on "National" graphite stool inserts, write to National Carbon Division, Union Carbide and Carbon Corporation, Dept. IS.

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UNION CARBIDE AND CARBON CORPORATION
30 East 42nd Street, New York 17, N. Y.

District Sales Offices: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco

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MORE THAN DOUBLE THE USABLE LIGHT!

The biggest news since the invention of flashlights—the brand new leakproof "Eveready" No. 1050 flashlight battery—gives more than double the usable brilliant white light for critical uses than any other flashlight battery we have ever made. NO METAL CAN TO LEAK OR CORRODE.

Personnel News...

William H. Yeckley, formerly general superintendent of Youngstown Sheet and Tube Co.'s Campbell works steel plant, blast furnaces and Struthers works and **Dr. Karl L. Fetters,** formerly special metallurgical engineer, have been named assistants to the vice president in charge of operations at Youngstown, Ohio.

Robert G. Riegel was appointed superintendent of the new electric weld pipe mill at Kaiser Steel Corp., Fontana, Calif. Mr. Riegel came from Republic Steel Corp., Youngstown, Ohio, where he had been general foreman for the past ten years.

J. L. Tatman has been named assistant superintendent, rolling mills, National Tube Company, McKeesport, Pa.. Mr. Tatman was superintendent, blast furnaces, Steubenville-South, Wheeling Steel Corp., Mingo Junction, Ohio.

James P. Williams has been appointed division manager, engineering and planning for Kaiser Steel Corp., Fontana, Calif. He was formerly chief industrial engineer. **Bruce Claflin** has been appointed chief industrial engineer. **Robert T. Richmond** and **Ralph L. Vaughn** were named divisional industrial engineers.

F. S. Mallette was appointed to the post of assistant director of research—air and stream pollution control, American Steel & Wire Co., Cleveland, Ohio. Mr. Mallette, who presently is completing work on his doctorate degree at the University of Chicago, has been pursuing the study of industrial toxicology and solving industrial pollution problems for the past 25 years.

J. P. Keller, formerly superintendent of all generator and turbine bucket manufacturing for the turbine divisions of General Electric's apparatus department, has been recently appointed as assistant to the manager, industrial divisions. Named to replace Mr. Keller was **L. E. Newman,** previously assistant manager of the G-E Lynn, Mass., turbine and gear sales division.

James A. Gilruth, formerly advertising and sales promotion manager of Gould Storage Battery Corp., Trenton, N. J., has joined Harry W. Smith, Inc., New York publicity firm specialized to serving industrial advertising agencies and manufacturers with technical markets. Mr. Gilruth will be senior editor and heavily emphasize new account development.

Raymond H. Cramer was named general manager of Hyatt Bearings division of General Motors Corp., Harrison, N. J. Mr. Cramer has been works manager of the Hyatt Bearings Division.

Edward P. Buchanan was named manager of the pig iron division of Pittsburgh Coke & Chemical Co. Mr. Buchanan has been in the company's sales organization for a period of twelve years except for two and one-half years during the war when he was the assistant to the chief of the pig iron section of the War Production Board. Prior to his affiliation with the Pittsburgh Coke & Chemical Co., Mr. Buchanan was with the Pittsburgh Steel Co. for five years.

Harrison D. Beale has been appointed manager of the renewal parts division, industrial divisions, of the General Electric Co.'s apparatus department.

E. T. Warren has been elected president of Tata, Inc., New York, N. Y. Mr. Warren has held the position of vice president of this corporation since his return from India in 1949.

Carroll B. Mershon has joined the Tate-Jones division of Continental Equipment Co., Coraopolis, Pa., and will manage and direct the sales of industrial burners and auxiliary furnace equipment. Mr. Mershon, a graduate of Iowa State College in chemical engineering, was industrial gas engineer for the Manufacturers Light & Heat Co. from 1930 until 1945. At the time of his resignation he was manager of industrial and commercial sales. He entered into the industrial furnace business in 1945 with the Pennsylvania Industrial Engineers, and for the past three years has been sales engineer with Olson Engineering Co.

Walter C. Mason has been appointed district resale manager, Atlantic district, General Electric Co., with headquarters in Philadelphia, Pa. Prior to his new position, he was assistant manager of the Pittsburgh apparatus sales office. Mr. Mason joined the General Electric Co. in the student engineering course in 1930. This followed his graduation from Pennsylvania State College, with a B.S. degree in electrical engineering. In 1937 he was transferred to the Pittsburgh office and assigned to the steel mill sales section. In 1945 Mr. Mason was appointed assistant manager of the Pittsburgh sales office, which position he held to the present time.

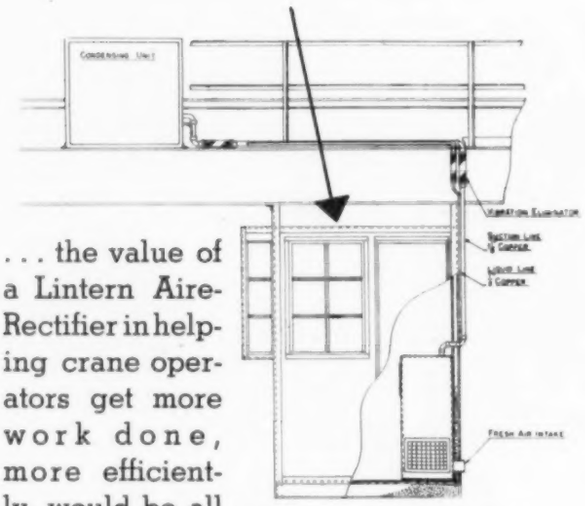
WILLIAM H. YECKLEY

DR. KARL L. FETTERS

ROBERT G. RIEGEL

JOHN L. TATMAN

IF YOU DID YOUR WORK IN A CRANE CAB . . . .
(WITHOUT AIR CONDITIONING)



. . . the value of a Lintern Aire-Rectifier in helping crane operators get more work done, more efficiently, would be all the more apparent.

The new cab unit of the Lintern Aire-Rectifier is greatly reduced in size and easily located in cab.

Highly efficient, thoroughly dependable, this practical air-conditioning unit is one of the best investments you can make in improving the efficiency of crane operation and building employee good will.

A decade of experience with hundreds of installations, under virtually all kinds of conditions, is back of our recommendations. Why not tell us your conditions and let us quote you?

THE LINTERN CORPORATION

54 LINCOLN AVENUE BEREA, OHIO

Frank L. Headley has been named assistant manager of the General Electric apparatus sales office, Pittsburgh, Pa. Mr. Headley joined the General Electric organization as a member of the test course immediately following his graduation from South Dakota State College in 1923, with a B.S. in electrical engineering. After several years in the engineering and selling phases of the business, he became Atlantic district transportation manager in 1945, and in January, 1948, he was made manager of the central station and transportation divisions, Philadelphia office. On January 1, 1949, he was appointed manager of the Philadelphia apparatus sales office, which position he held until his new appointment.

E. W. Nick, formerly president of the Northern Equipment Co., Erie, Pa., a division of Continental Foundry & Machine Co., has been elected chairman of the board. **George L. Davis** has been elected president of the Northern Equipment Co. to succeed Mr. Nick.

Milton H. Jacob was named director of personnel relations for Jones & Laughlin Steel Corp. Mr. Jacob has served as assistant director of personnel relations since 1947.

Joseph van Ackeren, vice president and assistant general manager, engineering and construction division, Koppers Co., Inc., has announced his retirement from active management. Mr. van Ackeren, a widely known engineer in the coke oven construction field,

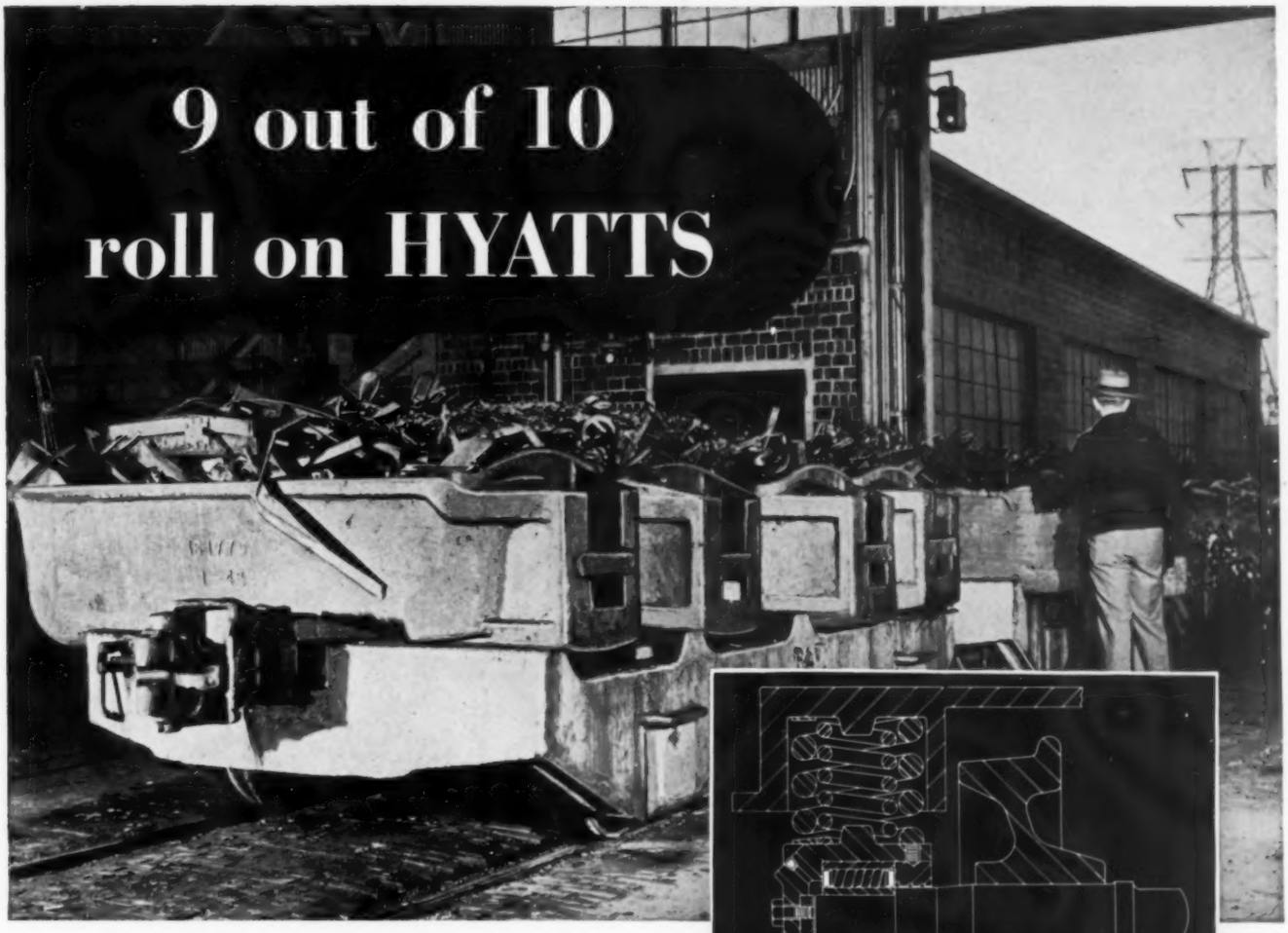
GEORGE M. CARVLIN

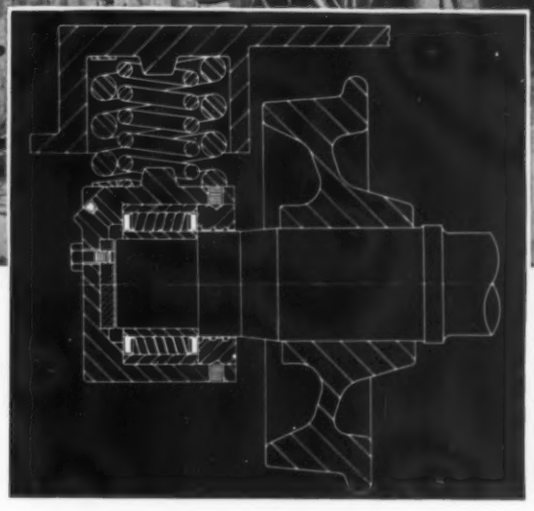
has been retained, however, by Koppers as a consultant. **George M. Carvlin,** vice president, engineering and construction division, Koppers Co., Inc., has been made assistant general manager of that division.

D. L. Clark, superintendent of melting, Simonds Saw and Steel Co., Lockport, N. Y., has been elected 1950 president of the Electric Metal Makers Guild, Inc. **C. C. Spencer,** superintendent of melting, Electric Steel Casting Co., Indianapolis, Ind., was elected vice president and **R. J. McCurdy,** superintendent of melting, Republic Steel Corp., South Chicago, Ill., was elected secretary-treasurer.

Frederick G. Schmidt, who has been assistant to the president, has been appointed manager of the new small circuit breaker division of the I-T-E Circuit Breaker Co., Philadelphia, Pa. Mr. Schmidt will direct sales, engineering, manufacturing and associated activities of the division.

9 out of 10 roll on HYATTS





Among the builders of Hyatt Equipped Charging Cars are the Union Steel Casting Division of the Blaw-Knox Company whose cars are illustrated above.

There are many good reasons why over 90% of the ingot and charging cars are operating on Hyatt Roller Bearings.

It takes less tractive effort to move a string of cars, more cars can be handled with same amount of power, lubrication is less frequent, axle wear is reduced and axle breakage virtually eliminated.

Hyatts protect all operating equipment, no matter how extreme the conditions or heavy the loads—indoors or out.

For your cars, as well as tables, cranes, mill motors and auxiliary equipment look to Hyatt for dependable bearings. Hyatt Bearings Division, General Motors Corporation, Harrison, N. J.

HYATT ROLLER BEARINGS

Roy M. Smith, has been appointed chief engineer and **Roy H. Albright**, assistant to the chief engineer by Railway & Industrial Engineering Co., Greensburg, Pa. Mr. Smith has been distribution engineer for the company since 1945, and previously served as chief engineer of Roller-Smith Co.; engineering manager, Bryant Electric Co.; engineer, Pacific Electric Co., and for 17 years was connected with Westinghouse Electric Corp. Mr. Albright has been design and application engineer for the company.

C. A. Kral, management representative for Koppers Co., Inc. in Chile, where Koppers are building an integrated steel plant for Pacific Steel Co. of Chile, has been appointed vice president in charge of operations and construction of the latter firm. He continues as Koppers' management representative.

Harry G. Potts, district sales manager of Pennsalt's heavy chemicals department, will be in charge of the new district sales office of Pennsylvania Salt Manufacturing Co. in Detroit, Mich. The office is at 1114 Buhl Building, 535 Griswold Street, Detroit. Also making their headquarters there will be **W. B. Adam**, heavy chemicals sales representative, and **Willis J. Stoddard** of the special chemicals department.

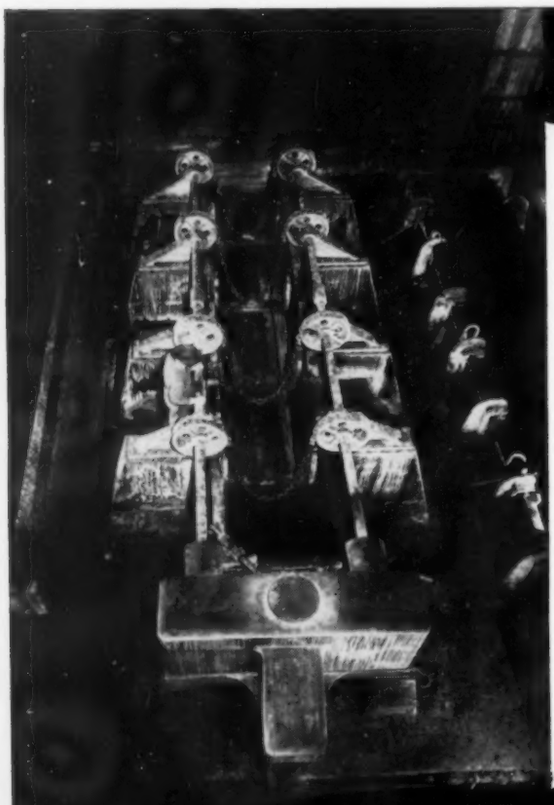
With the opening of the new Detroit office, Pennsalt is discontinuing its former sales office at its Wyandotte plant.

Lawrence J. Kline was appointed general manager of the Automatic Transportation Co., a division of Yale and Towne Mfg. Co., Chicago, Ill. Mr. Kline succeeds **Elmer F. Twyman**, who has been elected vice president in charge of the Philadelphia division of Yale & Towne. Mr. Kline joined Automatic earlier this year as sales manager, after having served the Mercury Manufacturing Co., Chicago, Ill., as executive vice president.

LAWRENCE J. KLINE

Obituaries

Alfred W. Gregg, consulting engineer for Whiting Corp., Harvey, Ill., died June 8.



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PICKLING OPERATIONS

LET THE NEW
WELDCO
MECHANICAL PICKLER

Are you pickling bars, tubing, rounds, flats, squares, or hexagons? Then it will pay you to check these 7 big advantages of the new WELDCO Pickler:

1. Saves 40 to 60% pickling time.
2. Saves on man power, steam, and maintenance work.
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4. Mechanical operation provides a more vigorous pickling action, exposing all surfaces to the solution and speeding scale removal.
5. Can be built to any capacity.
6. Can be made to fit any type plant.
7. Simplicity in operation and control—no complicated mechanism.

Call or write for complete information on the new, easy-to-use Mechanical Pickler. Our trained engineers will be glad to advise you on such matters as pickling plant layout and design, pickle liquors, temperature control, ventilation, and selection of tanks.

Other WELDCO Pickling Products include Pickling Crates, Baskets, Chains, Hairpin Hooks, Jets, and Scrubbers. Catalogs available on request.

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MODERN *HIGH-SPEED* COLD STRIP MILLS

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ROLLING MILLS AND ROLLING MILL EQUIPMENT

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Pittsburgh 22, Penna.

Obituaries

(Continued)

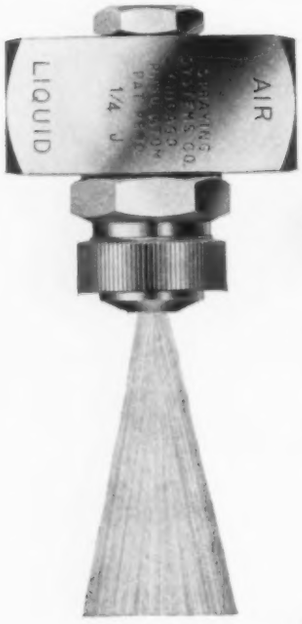
George W. Pressell, 62, vice president of E. F. Houghton & Co., Philadelphia, Pa., died June 5. Mr. Pressell was the oldest Houghton employee in point of service, having started as a messenger boy 47 years ago at $2.00 a week. He had held offices of chief chemist, secretary, second vice president, general sales manager and director of sales. Since 1919 he had been a member of the board of directors. He was also president of E. F. Houghton & Co. of Canada, Ltd.

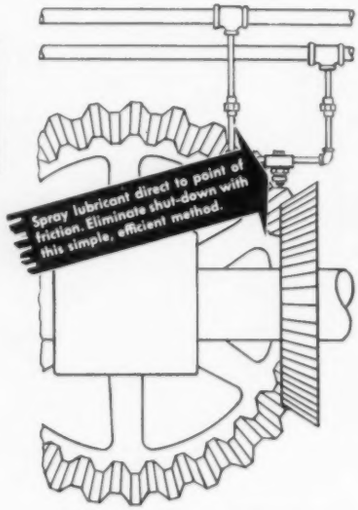
H. O. K. Meister, 62, general manager of the Hyatt Bearings division of General Motors Corp., Harrison, N. J., died June 10. Mr. Meister had been general manager of the Hyatt plant since 1937.

Purlee Ruff, 76, vice president of Mechanics Supply, Inc., died June 3. Mr. Ruff had been previously with J. Frank Lanning and Co. and Tidewater Associated Oil Co.

J. Evan Morgan, 52, assistant packaging and leading engineer for the Carnegie-Illinois Steel Corp., Pittsburgh, Pa., died June 19.

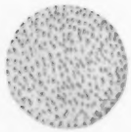
Use
THE ENGINEERING MART





direct-to-gear lubrication with SPRAY NOZZLES

Spraying Systems Pneumatic Atomizing Nozzles provide efficient, low cost lubrication for gears or other moving parts. Lubricant materials from very light oils to greases may be successfully sprayed. Advantages of this method are that lubricant is applied where required without need of shut-down . . . and the system does not have to be an in-built part of the machine.



Write for Data Sheet 4516 and complete information on Spraying Systems Spray Nozzles for steel mill application.

SPRAYING SYSTEMS CO. 3262 RANDOLPH STREET BELLWOOD, ILLINOIS
(Suburb of Chicago)

BROWNING MILL TYPE CRANES have *Plenty of Strength* WHERE STRENGTH IS NEEDED!

Browning Mill Type Cranes are built in accordance with A. I. S. E. specifications. They incorporate the types of motors and controls on which your mill or industry has standardized. This flexibility adapts your VRB crane *perfectly* to your needs. Only the finest materials are employed. Browning heavy duty cranes meet the most rigid demands and satisfy the most critical users. Our design, placing plenty of strength wherever needed, is the outgrowth of 48 years' experience in the crane industry.

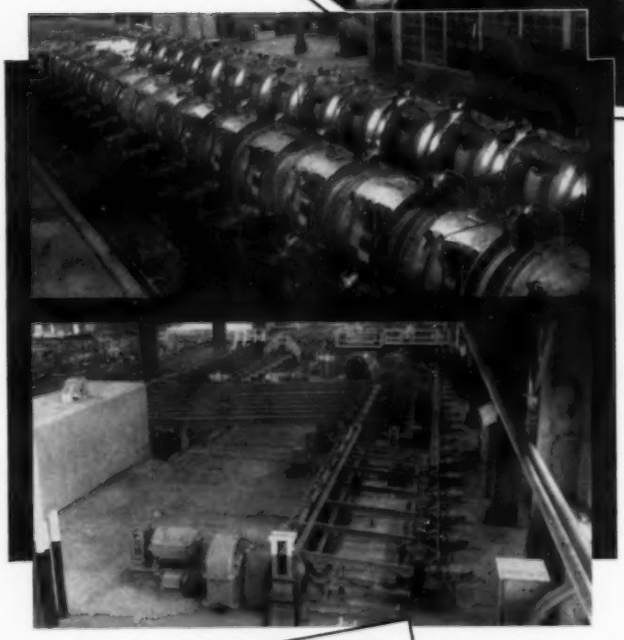
"Built as you yourself would build them"

Write for our Bulletin "S".

VICTOR R. BROWNING & COMPANY, Inc.
BOX 309, WILLOUGHBY (CLEVELAND), OHIO
Designers and Builders of Electric Overhead Traveling Cranes and Hoists and Electric Revolving Cranes

NATIONAL TUBE COMPANY'S
NEW Seamless Tube Mill

Mechanically Installed by EICHLEAY



Eichleay mechanically installed the new Seamless Tube Mill at the Gary Works of the National Tube Company.

Our background of long experience plus complete modern equipment enables us to undertake the precision installation of all types of machinery and the relocation of industrial units.

Other services — Complete Plant Erection — Structural Steel Erection — Foundations for Buildings and Equipment — Shoring — Rigging, Underpinning — Moving of Buildings and Machinery.

Write for illustrated booklet.

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EICHLEAY CORPORATION

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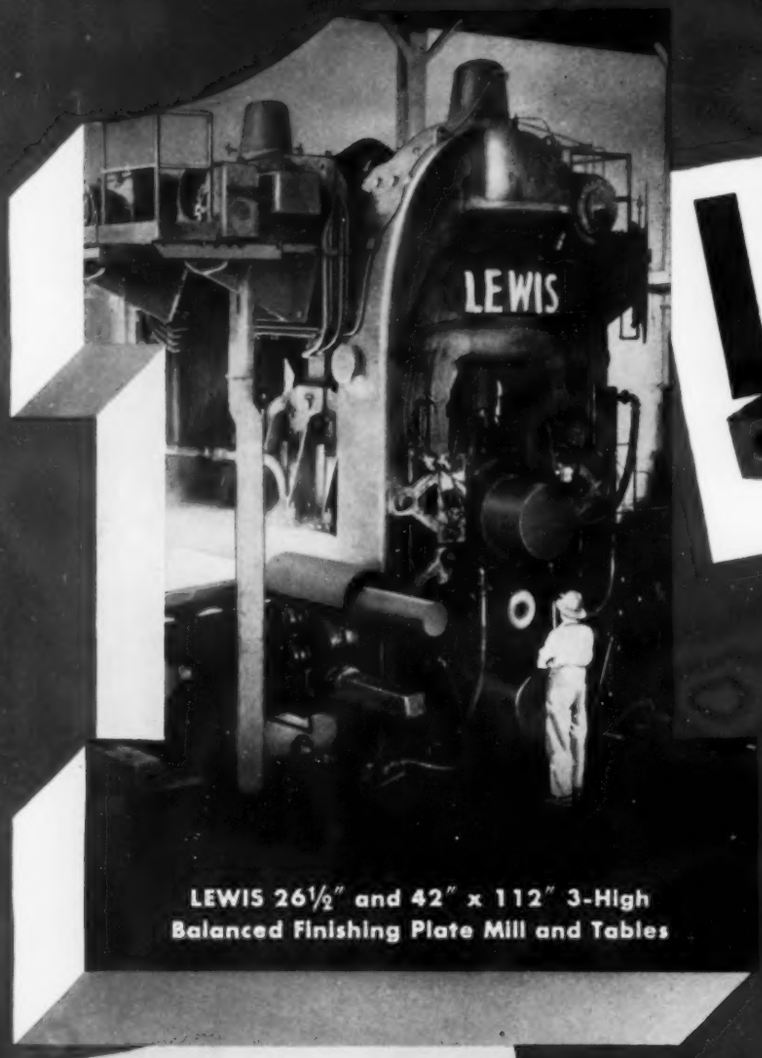

LEWIS 26½" and 42" x 112" 3-High
Balanced Finishing Plate Mill and Tables

LEWIS
ROLLING MILL EQUIPMENT

St...

LEWIS Standard Roll Lathe
Floor-mounted Motor

LEWIS 4-High Foil Mill — Entry Side

in the hearts of MILL OPERATORS

BEDS — Cooling
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HOUSING PINION — Rolling Mill
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MACHINES — Pickling
MANIPULATORS — Rolling Mill
MILLS — Aluminum Foil • Bar • Billet and Blooming • Brass and Copper • Cold Rolling • Continuous • Edging • Four-High • Single Stand • Reversing and Tandem • Merchant • Plate Rolling • Precision • Sheet and Strip • Slabbing • Three-High • Tin Plate • Universal • Wire • Zinc Strip • Roughing and Finishing
REELS — Tension
ROLL RAGGING ATTACHMENTS
ROLL POLISHERS
ROLLS — Alloy Iron • Chilled Iron • Sand and Chilled Iron • Steel
SAWS — Hot and Cold
SCREWDOWNS — Motor Operated • Hand Operated
SHEARS — Alligator • Bar • Billet • Bloom • Continuous Automatic • Sheet Mill • Gate or Guillotine • Lever • Plate • Power Driven • Scrap • Vertical
STRAIGHTENERS — Angle • Bar • Rails and Shapes
TABLES — Blooming Mill • Rolling Mill Feed • Transfer for Mills

LEWIS FOUNDRY & MACHINE
Division of Blaw-Knox Co., Pittsburgh, Pa.
Designers and Builders of Rolls and Rolling Mill Equipment

IN STEEL MILL POWER PLANTS

WITH MULTIPLE-FUEL BOILERS

. . . this nameplate identifies the Pneumatic Combustion Control System which efficiently and automatically compensates for fuel changes—and continues to do so throughout the life of the boiler.

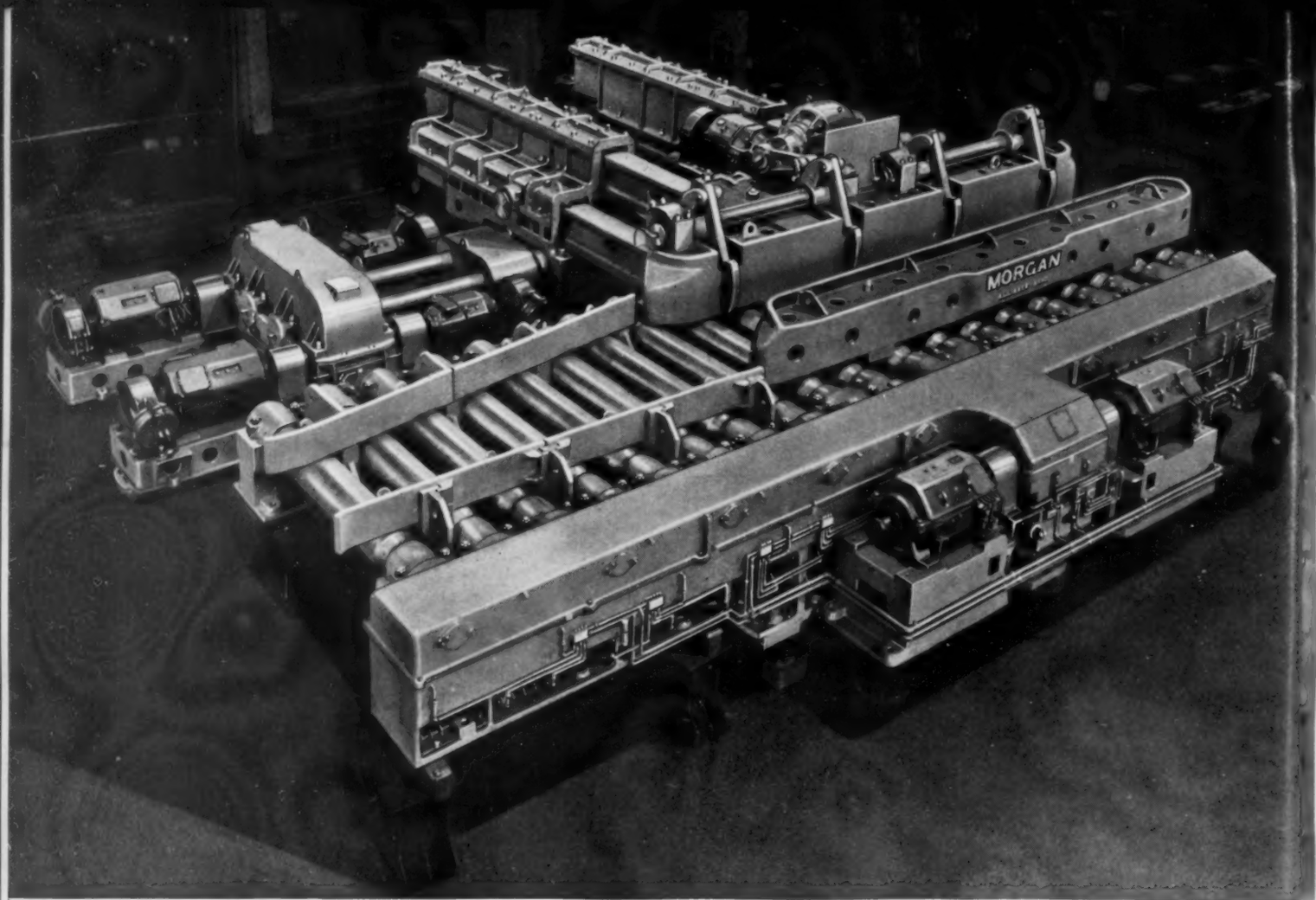
That is why, in such steel mill service, Hagan installations far outnumber any other type.

Hagan Corporation, Hagan Building, Pittsburgh 30, Pa.

HAGAN HALL BUROMIN CALGON

HAGAN CORPORATION

METALLURGICAL FURNACE CONTROL SYSTEMS
RING BALANCE FLOW AND PRESSURE INSTRUMENTS
BOILER COMBUSTION CONTROL SYSTEMS
THRUSTORQ FORCE MEASURING DEVICES



45″ BLOOMING MILL TABLE AND MANIPULATOR

Morgan 45″ Blooming Mill Manipulator with Front Mill Table. Manipulator is of the overhead type, electrically driven, with retractable heads so the table rollers can be removed without dismantling the manipulator heads. Table girders are of cast steel box section type with integral oil trough on drive side. All gears are totally enclosed, operating in oil, and have hardened teeth. All bearings are of the anti-friction type lubricated through a centralized motor operated system.

BUILT BY MORGAN Engineering

THE MORGAN ENGINEERING CO.

ALLIANCE, OHIO PITTSBURGH—1420 OLIVER BUILDING

DESIGNERS • MANUFACTURERS • CONTRACTORS • BLOOMING MILLS • PLATE MILLS STRUCTURAL MILLS • ELECTRIC TRAVELING CRANES • CHARGING MACHINES • INGOT STRIPPING MACHINES • SOAKING PIT CRANES • ELECTRIC WELDED FABRICATION • LADLE CRANES • STEAM HAMMERS • STEAM HYDRAULIC FORGING PRESSES • SPECIAL MACHINERY FOR STEEL MILLS

DEVELOP TEMPLATE-CONTROLLED LATHES FOR CONTOUR TURNING OF ROLLS

▲ Broadening further its line of cost-cutting, time-saving turning equipment, the Monarch Machine Tool Co. has developed two template-controlled engine lathes specifically for the contour turning of steel mill rolls up to 20 in. and 15 in. diameter, respectively.

The new machines, identified as "Model NN Roll Turning Lathe" and "Model N Roll Turning Lathe," were designed to utilize fully the cost-reducing possibilities of recently improved carbide cutting tools.

Both models are smaller scale adaptations of the "Monarch Heavy-Duty Roll Turner" which, introduced by the company just a year ago, pioneered the development of the template control method for contour turning all size rolls up to 25 in. in body diameter. The new units incorporate the same basic performance features as the original machine, but with the economies inherent in smaller machines applied to smaller size jobs.

Use of this technique during the past year has grown rapidly, having amply demonstrated its ability to effect substantial savings in steel mill roll-turning costs. These overall economies are made possible in at least seven ways:

1. Reduction of floor-to-floor turning time, ranging from 50 per cent to as much as 90 per cent on even the toughest chilled cast iron rolls.
2. Standard carbide turning tools with regular tool grinds are used, eliminating the need for hundreds of form tools involved with previously conventional roll turning methods.
3. Template control of contour forming eliminates matching rolls in pairs as formerly required.
4. When redressing a roll, operator can quickly check point of greatest wear with corresponding point on template after which entire roll cleans up on first pass.
5. Same template is used for both rough and finish passes; hence, finishing immediately follows roughing with no set-up change other than the required tool change.
6. As each roll turned from the same template is identical, the possibility of an operator inadvertently modifying the shape of the roll is avoided.
7. Longitudinal placement and relationship of template form and the forms to be turned on the roll are accurate as the former is dimensionally the same as the latter.

Monarch engineers anticipate that with the development of these two smaller roll turning lathes still further impetus will be given the trend toward roll turning by template control. They point out with three units of different capacities available, steel mills will be able to meet their particular roll turning requirements more economically by selecting the machine of the capacity best suited to meet the specific turning needs.

Performance features are the same with all three machines. For example, rolls are turned on centers, permitting necks to be handled during the same set-up. Work may be loaded and unloaded faster than when neck supports are used.

Again, in contrast to conventional roll turning lathes employing surface cutting speeds up to 100 in. per minute, the new Monarch machines in many instances utilize an equal number of feet per minute. Also, since both headstock and tailstock centers rotate, work centers do not wear the centers in the rolls. Removable work centers make it practical to use any required angle of centers.

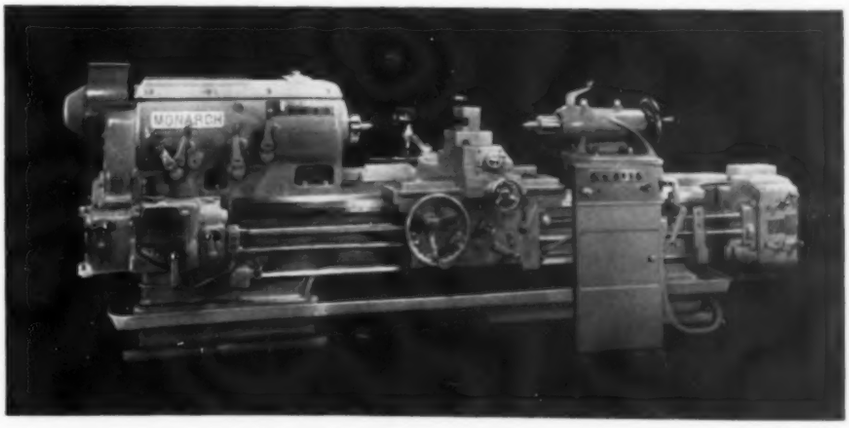
Model NN Monarch roll turning lathe is designed to accommodate rolls not exceeding 20 in. body diameter. Shallow passes may be taken just as fast as on any roll turning lathe and occasional deep passes also can be handled satisfactorily. Distance between centers is 132 in.

The Keller electrical contouring controls used consist of a magnetic clutch drive and feed change box, tracer mechanism, and pushbutton control from an electrical control stand, which may be located convenient to the operator. Stylus of the tracer mechanism, which follows a thin metal template mounted immediately below it at the rear of the machine, has three positions determined by very slight pressure changes against the template.

One position creates feed toward, the second creates feed parallel to, and the third position creates feed away from the center line of the machine. As variations in template contour change the stylus pressure against the template, magnetic clutches are engaged, actuating cross and longitudinal screws in their rotary motion. Response to change in template contour shape is practically instantaneous, the clutches from one direction to the other being energized or de-energized in $\frac{1}{125}$th of a second.

Of heavy-duty design, the headstock of the Model NN provides 16

Designed expressly for the contour turning of steel mill rolls up to 15 in. body diameter, this roll turning lathe brings substantial new economies to this type of work.



speeds from 8 to 405 rpm with an 1800 rpm motor. When the machine is to be used for turning a considerable number of rolls having body diameters approaching the maximum (20 in.), a face-plate drive headstock (optional) is recommended.

Drive to this headstock is either through the face plate or through the spindle in the conventional manner. It provides 24 changes in speed—16 speeds through the spindle drive from 10 to 55 rpm; 8 speeds through the face plate from 2½ to 15 rpm. In addition to permitting heavier cuts on large work, this headstock, due to its low speed range, makes it practical to turn rolls by the form tool method.

To provide rigid support for heavy work under all conditions, the Model NN is equipped with a new heavy-duty, angular-type tailstock. The standard tailstock with anti-friction center is supplied optionally where most of the rolls to be turned are in the smaller sizes.

Carriage, cross slide and tool block are of the heavy-duty type. The cross feed screw, extra large, is hardened and ground. The apron, of standard Monarch design, provides automatic lubrication to all working apron parts, the cross feed screw, bearing of cross slide on carriage and bearing of carriage on bed ways.

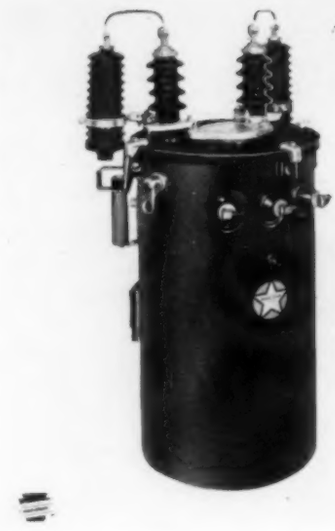
For contour turning of smaller rolls (up to 15 in. diameter), the Model N machine is recommended. Ordinarily, rolls of this size do not have deep passes, but the machine will handle an occasional deep pass if necessary. Distance between centers is 96 in.

Model N includes as standard equipment the 16-speed headstock, heavy-duty carriage and cross slide, heavy-duty tool post, tailstock with anti-friction center, Keller controls, and one set of either 60 or 70 degree centers.

NEW TRANSFORMERS HAVE MANY SAFETY DEVICES

▲Pennsylvania Transformer Co. has added the protected "Pole Star" transformers to its regular line of distribution transformers.

Protected "Pole Stars" are equipped with safety devices for maximum electrical protection. These devices include: Thermally operated circuit breaker which permits overloading of the transformer within safe limits yet provides protection against short circuits. Lightning arresters and tank discharge gaps which protect all three main points of insulation from lightning damage, i.e., high voltage to low voltage, high voltage to ground and low voltage to ground; protective links in the high voltage winding which prevent feeder lockouts due to faulted transformers; red signal light



The new transformer is equipped with safety devices for maximum electrical protection.

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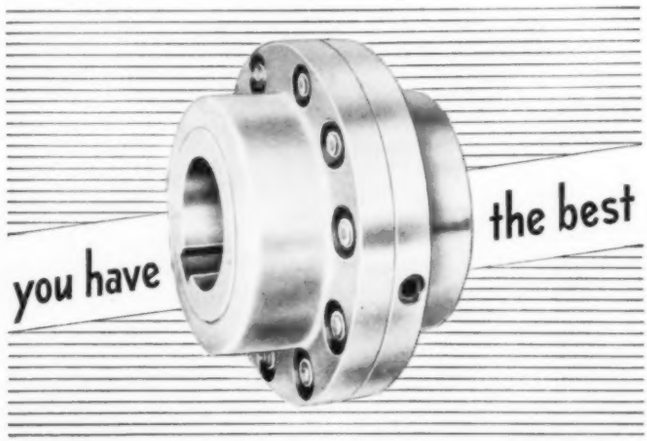

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To prove it just compare these "Series A" jobs with any other coupling of their type. Note the one-piece steel forged cover sleeve, the ample lining up surfaces, the absence of trouble making parts, the compact design and similar features. Our Catalog 57 will give you details. Write for it.

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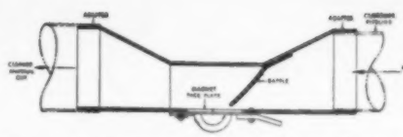
which glows and warns when loads have reached the danger point; breaker operating handle which, after the low voltage breaker has operated, enables the lineman to close the circuit and put the transformer back in operation; emergency breaker control which permits the transformer to carry greater overloads longer; and ground discharge gaps or ground connectors.

The new transformer combines this equipment and brings together in one compact unit all the accessories required for a complete transformer installation. They are available in sizes 3 kva through 100 kva, 14,400 volts and below.

MAGNET SEPARATES IRON IN GRAVITY FLOW PIPES

▲ Availability of a new permanent (non-electric) magnetic separator for removal of tramp iron from material flowing in round gravity flow pipes is announced by Eriez Mfg. Co. The unit features an adaptor which makes installation easy, adds to separation efficiency, and cuts costs.

The recently designed Eriez separator is a complete package of magnet and adaptor. To install the magnet in a pipeline the customer needs only to cut out a small section of his pipe where the magnetic protection is desired. At the inlet side the adaptor fits over the outside diameter of the pipe; at the outlet side it fits inside the pipe. This eliminates all fittings, gasket, leakage, etc.



The unit features an adaptor which increases efficiency.

Once installed the unit offers maximum magnetic protection, because the material being cleaned passes directly over the face plate of the magnet. It is suitable for use in the purging of tramp iron from all free-flowing materials conveyed in round gravity flow chutes.

Like other Eriez separators for industry, the new unit features permanent magnetism, with highest grade Alnico metal magnets. This means that no electric power or wiring is required. Operating costs are virtually negligible.

SAFETY SWITCH LINE IS IN FULL PRODUCTION

▲ Full production on Square D's newly designed 100 and 200 ampere safety switch line is announced by Square D Co.

The larger size switches conform to the general design features of 30 and 60 ampere sizes announced last fall. Type A switches for heavy duty industrial service include several exclusive design features—a full cover interlock that locks the switch "on" or "off." The cover can be locked, with 1, 2, 3 or 4 padlocks of varying sizes and shapes.

Current carrying parts of the new switches are silver plated, and blades are easily visible for quick checking of switch operation. Line terminals are dead-front, protected by a hinged arc chamber. Quick make and break action is assured by the simple mechanism with no dead center.

A magnetic plate in the arc chamber cover adds to the unusually high rupturing capacity of the new

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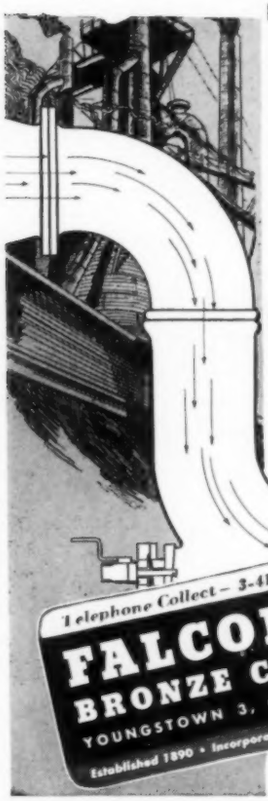

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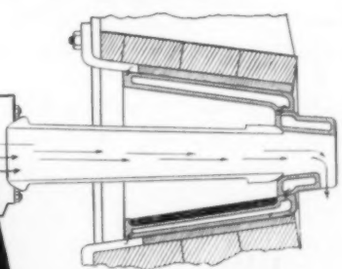

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Illustrated is an installation of Falcon-produced Kinney Refractory-Lined Tuyere Cooler, U. S. Pat. App. Serial 530153, and Holzworth "Split Nose" Tuyere, U. S. Pat. 1,789,870.

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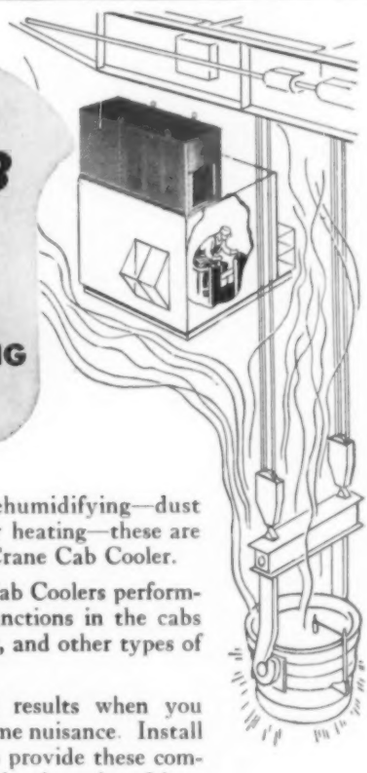

Cooling—fume removal—dehumidifying—dust filtering—ventilating—winter heating—these are the functions of the Dravo Crane Cab Cooler.

You will find Dravo Crane Cab Coolers performing these air conditioning functions in the cabs of soaking pit, ladle, stripper, and other types of hot-metal cranes.

And you will observe real results when you eliminate heat fatigue and fume nuisance. Install Dravo Crane Cab Coolers to provide these comfortable working conditions in the cabs of hot-metal cranes.

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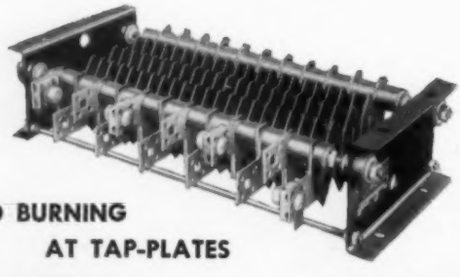

NO BURNING AT TAP-PLATES

EC&M TAB-WELD Plate Resistors provide the opportunity to reduce upkeep by a new construction which has shown excellent operating results.

This construction brings grid-eyes into intimate contact, eliminating the electrical connectors previously required between grids. Spot welding the tab-ends of the grids maintains the intimate contact and provides a continuous path without depending on the pressure of the end clamping nuts. Burning at tap-plates is also eliminated by spot welding the tap-plates to the ends of the mated grids.

In addition to elimination of trouble in concealed areas of the sections, EC&M TAB-WELD Plate Resistors have other cost-saving features. These are: stabilized resistance value, simplified tap-shifting with several tap-plates permitting convenient adjustment for best motor operation, metal tap-plate identification tags, corrosion-resisting qualities, etc. *Write for Bulletin 942 giving complete details.*

A reduction in preventive maintenance is a plus value—specify EC&M TAB-WELD Plate Resistors.

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switches. Jaws and fuse clips are steel reinforced to exert positive pressure.

A non-tracking insulation is used in the base. The insulating cross bar is formed of melamine. Pressure connectors are removable, so solder lugs may be used where preferred.

NEW PRIMARY BATTERY HAS MANY POSSIBILITIES

▲ A non-renewable, air-depolarized add-water type primary battery, the "Carbonaire," recently introduced by Thomas A. Edison, Inc., is expected to find application in many fields.

First widespread use will be in converting oil-burning railroad switch-lamps to electrical operation at a saving to the railroads of as much as $25 per lamp per year. This saving is possible because of the elimination of weekly or twice-weekly servicing. The new Carbonaire battery will supply enough electricity to keep a switch-lamp going for ten months to a year with only occasional inspections.

The present size Carbonaire, and others now being planned, will be suitable for many applications such as fire and burglar alarm systems, annunciator systems, elevator signals, laboratory apparatus, aids to navigation, telephone and telegraph installations, time clock systems, communication systems and other services that require a reliable, independent source of low voltage dc energy.

The 1000 ampere-hour model now in production contains two series cells sealed in a single, molded, hard rubber case. Dimensions are 8¼ in. x 7¼ in. x 9½ in. Like other primary batteries, the Carbonaire is not chargeable and is replaced when expended.

IMMERSION THERMOCOUPLE IS LIGHTER AND FASTER

▲ A lighter, faster and easier-to-use immersion thermocouple for measuring temperature of molten steel was announced last month by Minneapolis-Honeywell Regulator Co.

The thermocouple, about one-half the weight of previous designs, will be supplied in two forms. One will have a 90-degree bend for electric furnaces, the other a 60-degree bend for easy insertion through open hearth wickets. Both forms have six-foot handles. The immersion end of the thermocouple, excepting the immersion tip, is covered with a refractory compound.

The immersion end, except the tip, is covered with a refractory compound.

The new design, developed by the Republic Steel Corp., will be built

WHAT'S THE FASTEST WAY TO CLEAN METAL?
See page 11
WHAT'S THE MOST ECONOMICAL WAY?
See page 9
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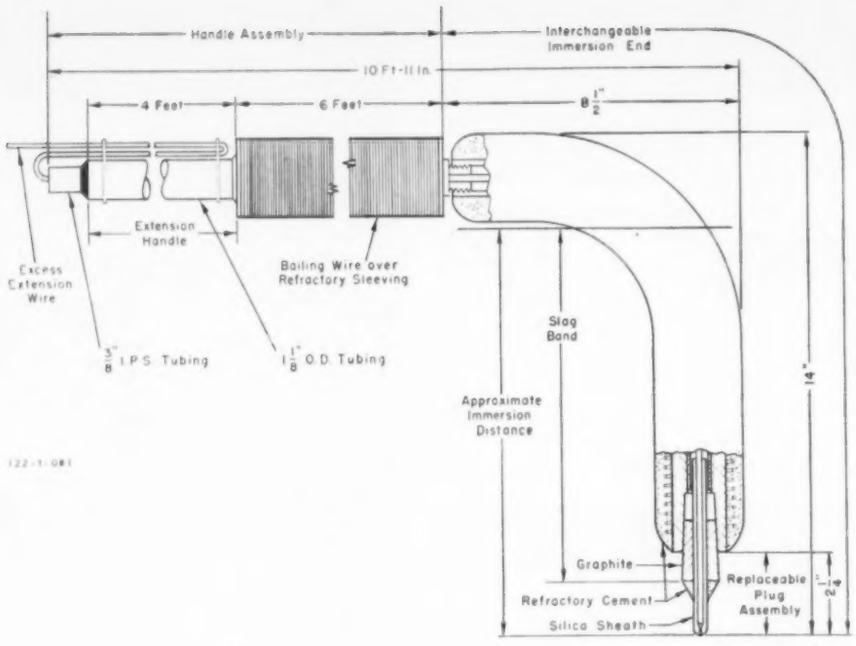

The complete assembly is about 11 ft long and weighs approximately 40 lb.

under license by Honeywell's Brown division at Philadelphia.

The complete assembly, handle and immersion end, is about 11 ft long and weighs approximately 40 lb. To make it more rigid, and to protect the thermocouple wires, the handle is built of two-layer seamless tubing having an outer covering of refractory sleeving. The platinum thermocouple wires extend from the extension wire at the handle, through the tubing and to the thermocouple tip.

Brown is offering the Republic immersion thermocouple assembly at $220; delivery, about eight weeks.

NEW IDEA FOR COOLING LARGE ENCLOSED MOTORS

▲ The Elliott "Unit-Cooled" design introduces a totally new idea for the cooling of large enclosed motors. A finned tube air-to-air heat exchanger, comprising a single rectangular unit, is located at the top of the welded-steel motor frame.

A fan draws cooling air from outside the motor, through the tubes, and out of the front of the motor enclosure. Air within the motor is passed over the finned tubes, cooled and recirculated.

For cleaning or inspection, removal of a single face plate exposes all cooling tubes and a wire brush or tube cleaner can be passed through them. If repair or replacement is required, the entire heat exchanger unit can be drawn out from the motor enclosure.

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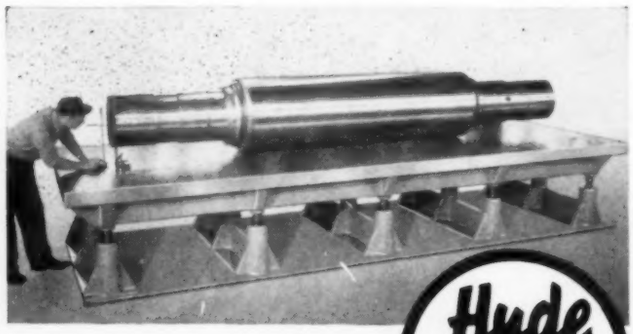

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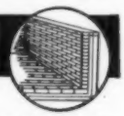
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FOR GENERAL ELECTRIC TYPE MD MILL MOTOR BEARING CHANGE-OVERS

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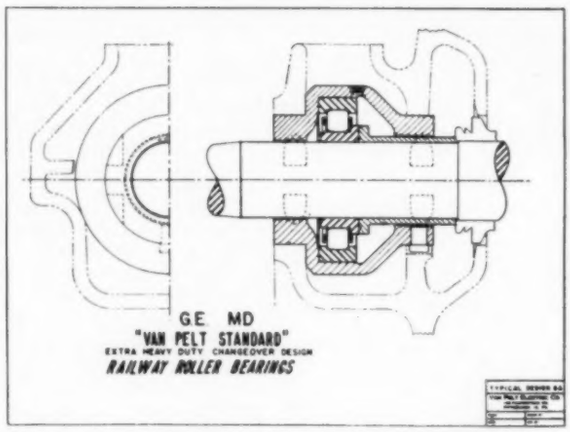

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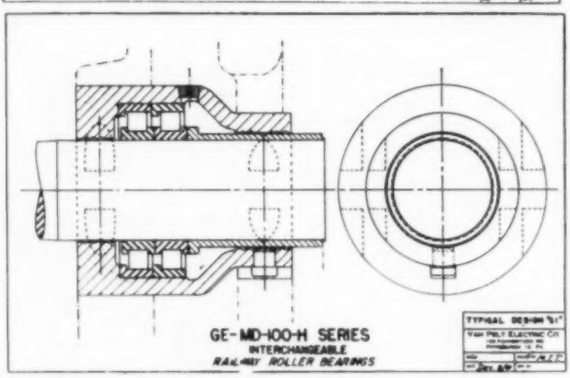
The best for least cost. This extra heavy duty design provides extreme life yet permits full interchangeability with the old sleeve bearing armature.



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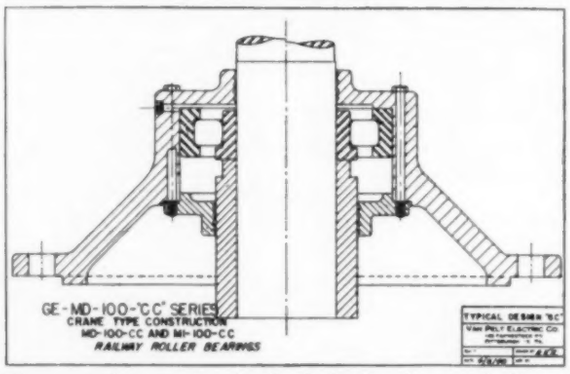

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105 FAHNESTOCK ROAD • PITTSBURGH 15, PA.

6,154,648 tons of steel rolled on this bearing lubricated by Farval

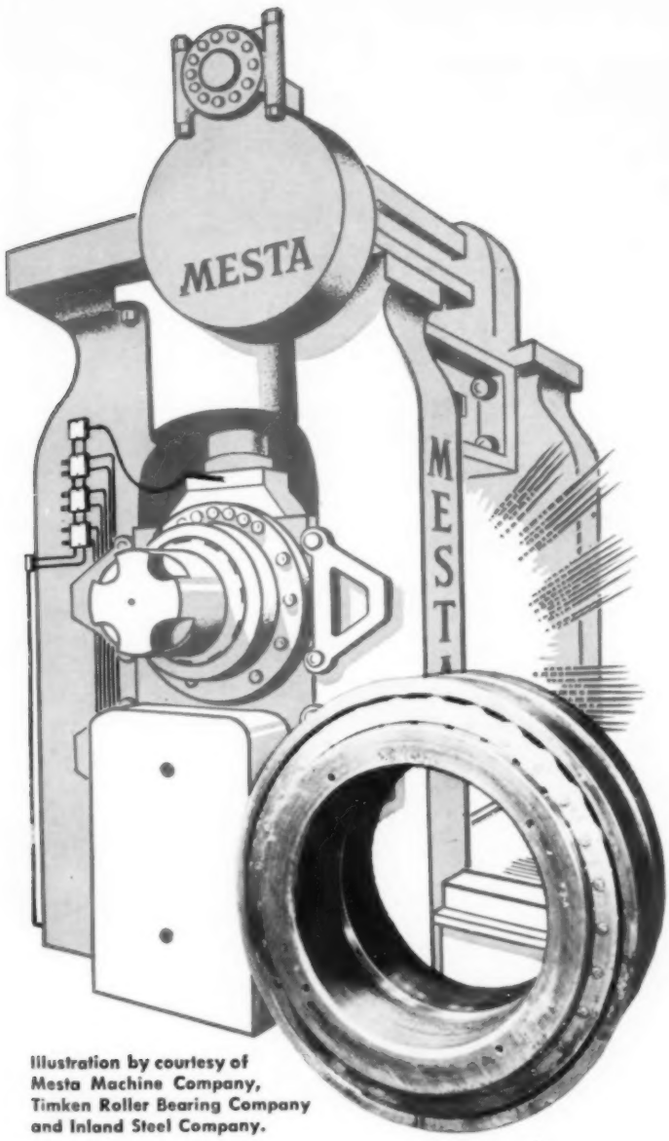

Illustration by courtesy of Mesta Machine Company, Timken Roller Bearing Company and Inland Steel Company.

FARVAL—*Studies in Centralized Lubrication* No. 116

EIGHTEEN years ago, this continuous hot strip mill was installed at the Inland Steel Company, Indiana Harbor Works, East Chicago, Indiana. It was then the last word in rolling mills, with roll necks equipped with Timken bearings and lubricated with three Farval Heavy Duty Automatic Lubrication Systems.

Since then this mill has rolled more than six million tons of steel. The Timken roll-neck bearing shown in this illustration, when removed for photographing, had a total of exactly 6,154,648 tons to its credit. Inspection at that time showed that the bearing was still in splendid condition, good for many thousand tons more. There has never been a bearing failure or an interruption of production because of inadequate lubrication—thanks to Farval.

Farval serves the vast majority of the world's hot strip mills—well over 70% of the mills in America and abroad. And since the original cold strip mill installations in 1930, more than 90% of all the continuous cold mills built have been equipped with Farval.

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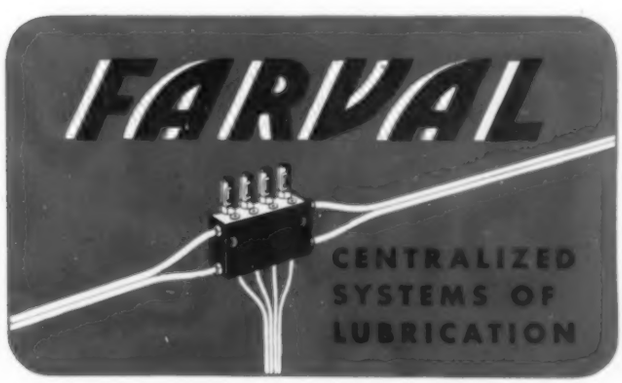

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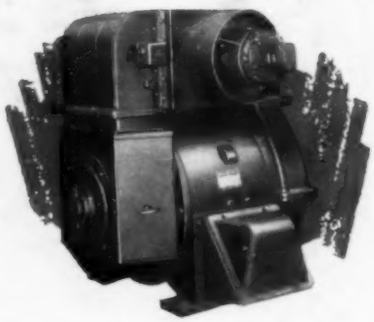

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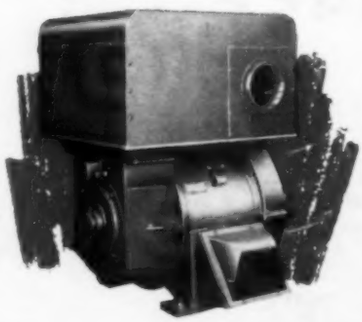

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